REPORT RESUMES

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ACCEPTABILITY OF A FUNCTIONAL-COSMETIC ARTIFICIAL HAND FOR YOUNG CHILDREN.

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DESCRIPTORS- *COSMETIC PROSTHESES, *AMPUTEES, CHILDREN, PHYSICALLY HANDICAPPED, PROSTHESES, NEW YORK CITY, APRL SIERRA CHILD SIZE MODEL NUMBER 1 HAND, DORRANCE NUMBER 10X HOOK

SEVENTY-SEVEN CHILDREN, AGED 4 YEARS TO 12 YEARS, 4 MONTHS AND EXEMPLIFYING ALL LEVELS OF UPPER EXTREMITY AMPUTATION (PROSTHETIC TYPE) FROM WRIST-DISARTICULATION TO SHOULDER-DISARTICULATION, WORE THE APRL-SIERRA CHILD SIZE MODEL NUMBER 1 HAND FOR APPROXIMATELY 4 MONTHS. CHILD AND PARENTS MADE FOUR CLINIC VISITS FOR INITIAL SCREENING, FITTING, 2 MONTHS POSTFITTING EVALUATION, AND FINAL EVALUATION. TWENTY-ONE CHILDREN WANTED TO WEAR THE HAND EXCLUSIVELY, 21 DESIRED IT FOR MOST ACTIVITES, SEVEN CHILDREN PREFERRED IT ABOUT EQUALLY TO A HOOK, EIGHT CHILDREN AND PARENTS DISAGREED IN PRIMARY CHOICE, 13 PREFERRED THE HOOK, AND SEVEN REJECTED THE HAND COMPLETELY. WHEN COMPARED TO THE EQUIVALENT DORRANCE NUMBER 10X HOOK, THE NUMBER 1 HAND PROVIDED LESS TOTAL FUNCTION, BUT EQUAL FUNCTION FOR NUMEROUS ACTIVITIES, AND SUPERIOR FUNCTION FOR SOME CHILDREN ON CERTAIN TASKS. THE HAND HELPED THE CHILD'S SELF CONFIDENCE, AND ACCEPTANCE BY PEERS AND TEACHERS. PRESCRIPTION OF THE HAND WAS RECOMMENDED FOR APPROPRIATE SIZE AND AMPUTATION LEVELS. THE AUTHORS SAW THE NEED TO REDUCE THE AMOUNT OF BREAKAGE OF THE HAND AND TO PROVIDE A MORE DURABLE GLOVE. A HOOK IS SUGGESTED AS A SPARE OR PLAY DEVICE WHEN PRESCRIPTION FOR THE HAND IS MADE. APPENDIXES INCLUDE DATA-GATHERING QUESTIONNAIRES AND CHART OF HAND MALFUNCTIONS. A SIX-ITEM BIBLIOGRAPHY IS INCLUDED. (MY)

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NEW YORK UNIVERSITY
College of Engineering
Research Division

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Child Prosthetic Studies
January 1964

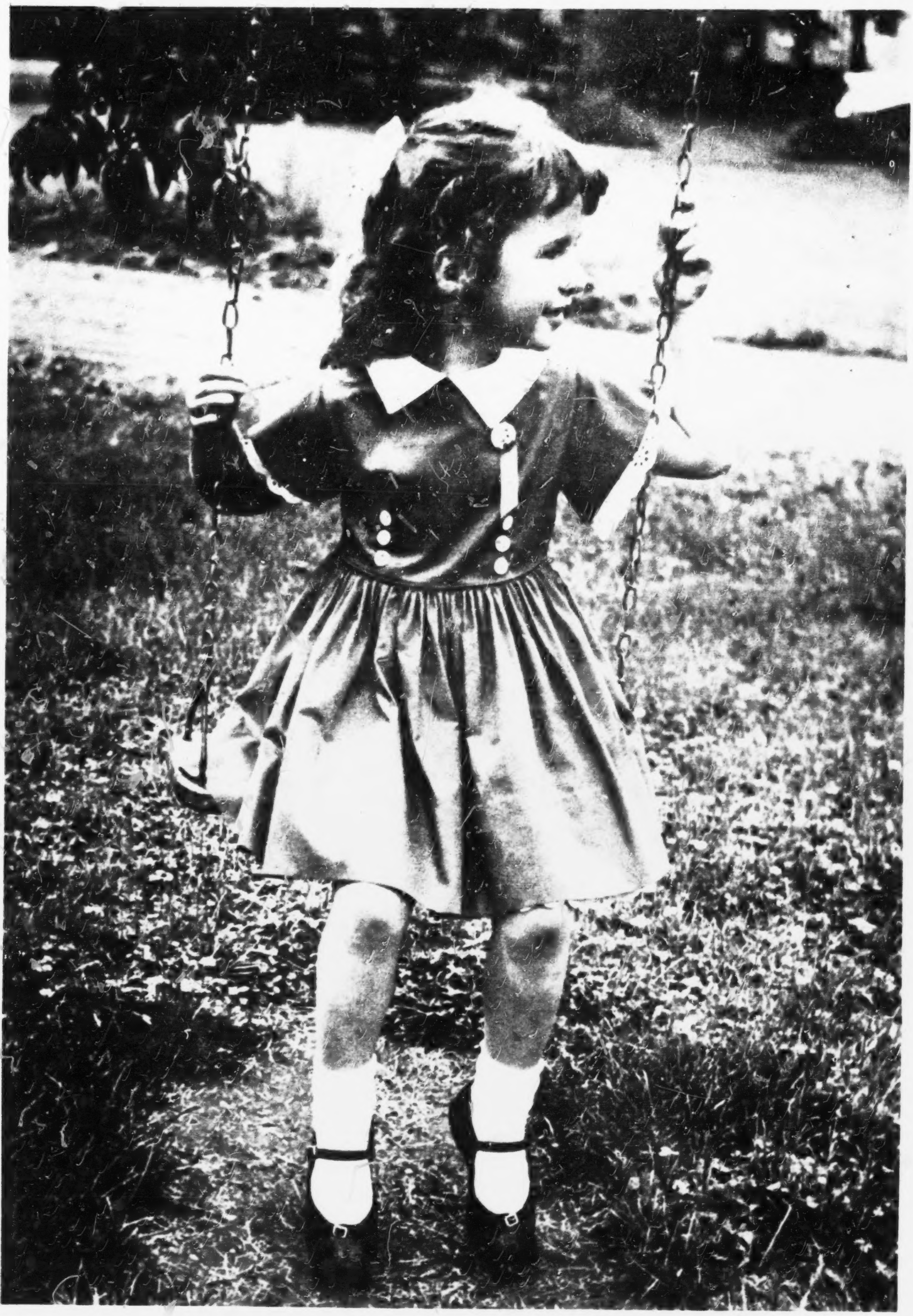

Plate I - Child Holding Swing with Artificial Hand

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Child Prosthetic Studies
Research Division
College of Engineering
New York University
New York, New York
January 1964

ACCEPTABILITY OF A FUNCTIONAL-COSMETIC ARTIFICIAL HAND FOR YOUNG CHILDREN

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Roberta Bernstein, Alfred Brooks, Herbert Bursky, Bertram Litt, Deborah Osborne and Dr. Edward Peizer, staff members of the Child Prosthetic Studies, have also made significant contributions at various stages during the development and testing of the APRL-Sierra Child Size No. 1 Hand, and in the preparation of this report.

These studies were conducted under the auspices of the Subcommittee on Children's Prosthetics Problems of the Committee on Prosthetics Research and Development, National Academy of Sciences-National Research Council: Dr. Charles H. Frantz, Chairman, Dr. Milo B. Brooks, Dr. Sidney Fishman, Col. Maurice J. Fletcher, U. S. Army (Ret.) and Dr. Arthur J. Lesser.

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The photographs of the hand and of children performing various activities with the experimental device are published by arrangement with the Institute of Physical Medicine and Rehabilitation, New York, New York, the Mary Free Bed Hospital of the Michigan Crippled Children Commission, Grand Rapids, Michigan, the Amputee Clinic of the Department of Orthopedic Surgery of the University of Illinois, Chicago, Illinois, and the Juvenile Amputee Clinic of the Florida Crippled Children's Commission, Orlando, Florida.

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ACCEPTABILITY OF A FUNCTIONAL-COSMETIC ARTIFICIAL HAND FOR YOUNG CHILDREN

INTRODUCTION

I. HISTORY

The need for a functional and cosmetically-acceptable hand for juvenile amputees has existed for many years. In 1958 the Army Prosthetics Research Laboratory attempted to fill the void by developing a child's voluntary-opening hand, denoted as size No. 1. The Sierra Engineering Company contracted to manufacture this hand, and two other companies (Kingsley Manufacturing Company and Prosthetic Services of San Francisco) were enlisted to manufacture suitable cosmetic gloves.

Following preliminary testing of a prototype model, modifications to eliminate certain shortcomings were incorporated in 50 production models. A field test was initiated in April 1960, with evaluation of the cosmetic gloves included as an integral part of the study. Preliminary findings based upon experiences in fitting 20 children were reported in October 1960 (1). The results indicated that the hand was acceptable cosmetically and provided satisfactory function in the activities typically performed by the children. The general workmanship and cosmesis of the gloves provided by both manufacturers had also achieved a satisfactory level, after certain initial fabrication difficulties. However, several problems had been identified during this phase of the study, the most serious of which was a lack of glove durability. Ridges and sharp edges on the exterior of the hand apparently contributed to rapid glove damage.

It was decided to modify the original production-model hands and then refit them to the subjects in the study. These modifications included the elimination of glove-cutting edges, strengthening of the floating-finger attachments and the spring mechanism of the thumb, and raising the cable exit. In November 1960 "old" hands revised in this manner began arriving at New York University-Child Prosthetic Studies and in April 1961 the manufacturer produced a series of new hands which incorporated all of the above modifications.

An Interim Report (2), summarizing the results of the field study to mid-May 1961, was prepared for the Subcommittee on Children's Prosthetics

Problems and the results reinforced earlier findings concerning the acceptability of the hand and gloves. The APRL-Sierra Child Size Model No. 1 Right Hand was accepted as satisfactory for general use by child amputees on the basis of this report, and the study was terminated in the latter part of 1961.

Following the generally successful outcome of the No. 1 Right Hand evaluation, manufacture of the No. 1 Left Hand was initiated. In May 1961, NYU-Child Prosthetic Studies reported the results of a preliminary examination of two units manufactured by the Sierra Engineering Company (3). The hands appeared to be of excellent quality and workmanship, with minor exceptions, and in June 1961 the manufacture of 55 additional left hands for field test purposes was authorized.

During September and October 1961 NYU-Child Prosthetic Studies received two shipments totaling 40 hands from the manufacturer. These were found to be unacceptable because of manufacturing deficiencies and all were returned for modification. It was not until February 1962 that 37 hands were finally accepted for use in the field study. Another 14 hands submitted later were also found to be suitable, for a total of 51.

Another Interim Report (4) on the status of the field study was submitted at the October 1962 meeting of the Subcommittee on Children's Prosthetics Problems. It was reported that the APRL-Sierra Model No. 1 Left Hand was considered to be essentially satisfactory both mechanically and functionally, although more rigid quality control in manufacture and assembly was desirable. The recommendations of this report -- that the hand and cosmetic glove be approved for commercial distribution -- was accepted by the Subcommittee and the study was terminated in January 1963.

II. PURPOSES OF THE STUDY

The APRL-Sierra Child Size No. 1 Hand (both Right and Left) was developed in order to provide the juvenile upper-extremity amputee with a cosmetically acceptable terminal device, which would closely resemble the normal hand in size, shape and coloring. Maximum function, commensurate with cosmesis, simplicity of operation, strength considerations and reasonable cost, was a concomitant objective.

Since the field study of the Left Hand was essentially an extension of the Right-Hand Study, the general goals of both evaluations were identical:

1) to introduce the hand into clinical use;
2) to corroborate findings of laboratory studies;
3) to determine the acceptability, utility, application, and durability of the production-model hand and glove;
4) to investigate indications and contraindications for prescription.

In the light of the experience gained in the prior Right-Hand Study, three considerations were given closer attention in the Left-Hand evaluation:

1) Performance differences between the experimental hand and the hooks previously worn were investigated in greater detail than was the case in the Right-Hand Study.
2) The short wear-life of the cosmetic gloves used in the Right-Hand Study presented a definite and challenging problem. In the course of the study the exterior of the experimental hand was extensively modified to eliminate sharp edges which might contribute to glove damage. The effectiveness of these changes was of particular interest in the Left-Hand Study.
3) The effect of hand wear on the child's school behavior was a planned aspect of the Right-Hand Study. Little data was secured on this significant subject, however, since the study overlapped two school years. With the earlier commencement of the Left-Hand Study (February 1962) these data were obtained for a limited number of children fitted during March and April 1962.

III. DESCRIPTION OF HAND

The APRL-Sierra Child Size Model No. 1 Hand, both right and left, consists of a metal handshell and two movable fingers (index and middle) which articulate at the inter- and metacarpo-phalangeal joints (Plate II). This type of articulation is designed to permit maximum finger travel without undue distortion of the cosmetic glove. The thumb may be set manually in two positions, with two finger-opening dimensions possible: with the thumb in the "small-opening" position gripping of objects 0 to 1-3/8" (minimum) should be possible, while the "large-opening" thumb position should accommodate objects 5/8" to 2" (minimum). Foam or silicon rubber floating fingers (ring and little finger) are attached to the handshell with an insert pin and are non-functional.

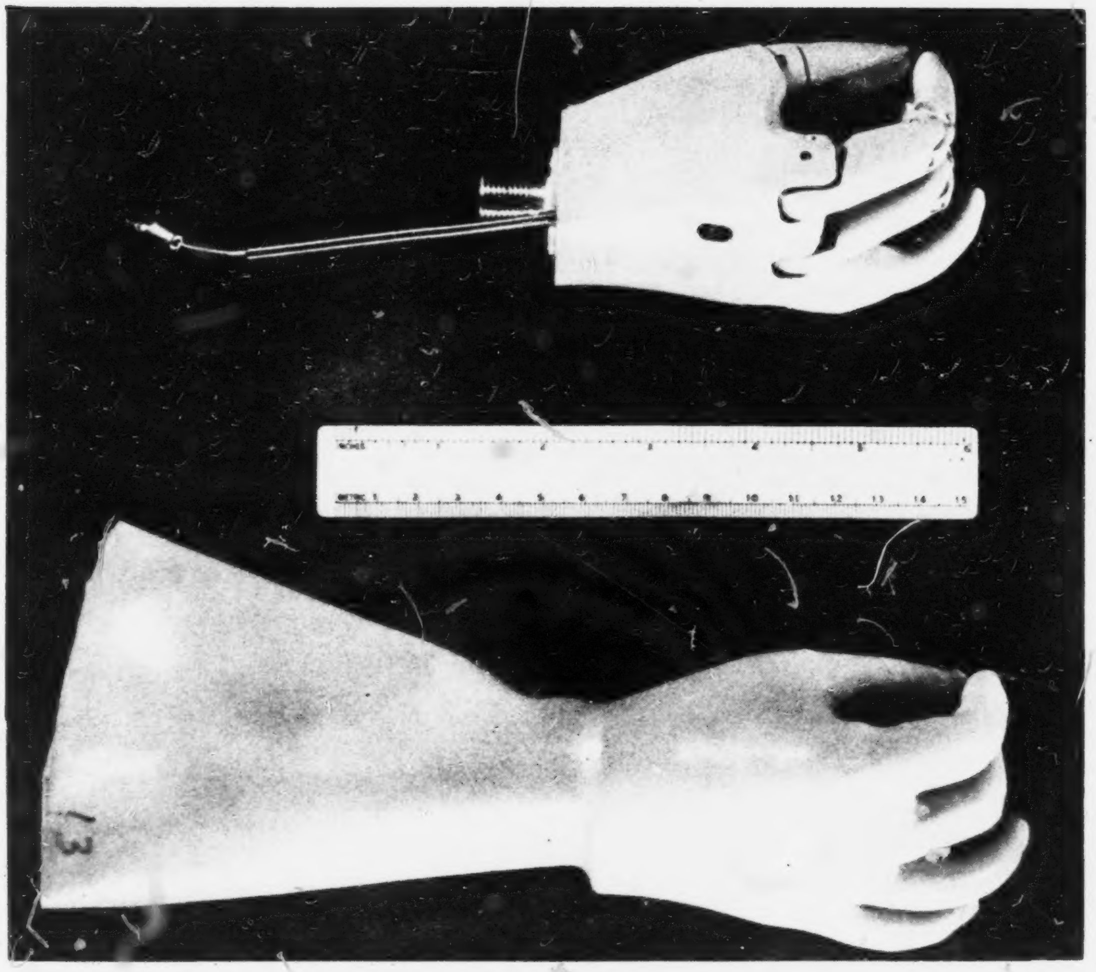

Plate II

APRL-Sierra Child Size Model No. 1 Hand

Hand function is of the so-called "voluntary-opening" type, i.e., a pull on the control cable opens the fingers against a spring force which closes them when the cable is relaxed. The hand mechanism provides a pinch force of approximately two pounds at the fingers and requires about ten pounds of force to open the fingers fully. Incorporated in the mechanism is a "following" lock or "Bac-Loc", which prevents the fingers from opening when a force or load up to a maximum of ten pounds is applied against them.

The hand is designed to be of life-like proportions and shape, so that a realistic appearance is attained when it is covered with the appropriate cosmetic glove. The specified overall dimensions of the hand are:

length (with fingers closed).................	3-5/8"
length (with fingers extended)...............	4-3/4"
width (at metacarpo-phalangeal joints).......	2-3/16"
thickness (at metacarpo-phalangeal joints of index finger and thumb)............	2-1/16"

Further details concerning the structural and functional characteristics of the No. 1 Hand may be found in the APRL Specifications Report 2-61 (5) and referenced publications.

SAMPLE

The sample, which embodied a variety of upper extremity amputee types, consisted of 77 subjects, one fitted with hands bilaterally. All the children in the study, except two, had previously worn Dorrance type hooks (Plate III).

Plate III
Boy Wearing Dorrance Hook

A total of 39 children, of whom 36 were unilateral arm amputees, were fitted with the right hand (see Table 1-R). Of the three remaining subjects, one (with bilateral shoulder-disarticulation amputations) was fitted with a right hand only and continued to wear a hook on the left side; one (with right above-elbow and left short below-elbow amputations) was also fitted with a right hand and retained a hook on the left; and a triple amputee (with bilateral long below-elbow and left knee-disarticulation amputations) was given hands on both sides. This latter subject was included in both the right- and left-hand samples.

Thirty-nine children, of whom 36 were also unilateral arm amputees, were fitted with the left hand (see Table 1-L). Of the three remaining subjects, one amputee (with bilateral shoulder-disarticulation amputations) was given a left hand only; a triple amputee (with bilateral long below-elbow and right below-knee amputations) received a left hand and kept a hook on the right; the third subject was the aforementioned triple amputee who was included in both samples.

TABLE 1-R

SAMPLE: APRL-SIERRA NO. 1 RIGHT HAND STUDY
(N = 39)

AGE	4		5		6		7		8		9		10		11		12		TOTAL	
SEX	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Partial Hand, Wrist-Disarticulation, or Long Below-Elbow	-	-	1	1	1	1	-	1	-	-	-	-	1	-	-	-	1	-	4	3
Medium or Short Below-Elbow	-	1	2	1	3	2	1	3	1	-	1	-	-	-	-	-	-	-	8	7
Very Short Below-Elbow	-	2	-	1	-	1	1	-	-	1	-	-	-	-	-	-	-	-	1	5
Elbow Disarticulation or Standard Above-Elbow	-	-	-	1	-	1	-	2	-	-	-	2	-	-	-	-	-	-	0	6
Shoulder-Disarticulation	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	0
Bilateral	-	-	-	-	-	-	-	1[a]	-	-	-	-	-	-	-	1[b]	-	-	0	2
Triple	-	-	-	-	-	-	-	-	2[c]	-	-	-	-	-	-	-	-	-	2	0
TOTAL	-	3	3	4	4	5	2	7	4	1	1	2	1	-	-	1	1	-	16	23

[a] Bilateral Shoulder-Disarticulation Amputations.

[b] Right Standard Above-Elbow, Left Short Below-Elbow Amputations.

[c] One boy had Right Short Below-Elbow, Left Syme, and Right Above-Knee amputations, and was the only child in the sample who had not worn an arm prosthesis before. The other boy had a Left Knee-Disarticulation and Bilateral Long Below-Elbow amputations and was fitted with hands on right and left sides.

TABLE 1-L

SAMPLE: APRL-SIERRA NO. 1 LEFT-HAND STUDY
(N = 39)

AGE	4		5		6		7		8		9		10		TOTAL	
SEX	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Partial Hand, Wrist-Disarticulation, or Long Below-Elbow	2	2	-	1	2	-	1	-	2	-	-	-	-	-	7	3
Medium or Short Below-Elbow	3	2	1	1	-	3	1	1	-	2	-	-	-	1	5	10
Very Short Below-Elbow	-	1	1	-	-	2	-	1	-	-	-	1	-	-	1	5
Elbow-Disarticulation or Standard Above-Elbow	1	-	-	1[a]	-	-	-	1	-	-	-	1	-	-	1	3
Shoulder-Disarticulation	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	0
Bilateral	-	-	1[b]	-	-	-	-	-	-	-	-	-	-	-	1	0
Triple	-	-	-	-	-	-	-	-	2[c]	-	-	-	-	-	2	0
TOTAL	6	5	3	3	2	5	3	3	4	2	-	2	-	1	18	21

[a] Plus Right Anomalous Hand and Foot.

[b] Left Standard Above-Elbow amputation and Right Paraxial Hemimelia (Ulnar). He wears no prosthesis on the right side.

[c] One boy had Right Below-Knee and Bilateral Long Below-Elbow amputations, and was fitted with the experimental hand on the left side. He continued to wear a hook on the right side. The other was the Bilateral Long Below-Elbow and Left Knee-Disarticulation amputee who was fitted with experimental hands on both sides and is included in both Right- and Left-Hand Study samples.

PROCEDURES

The fittings in both the Right- and Left-Hand Studies were conducted through the clinics participating in the Child Amputee Research Program. In order that wearers of the hand might secure the longest possible wear period before growth of the child caused an objectionable size discrepancy, it was recommended that the clinics select candidates whose non-amputated hand size was such that they would be able to wear the experimental hand for at least a year.

The experiences of the clinics were evaluated on the basis of (1) the reactions of the children, their parents, and others to the experimental hand and to other previously-worn terminal devices; (2) observations of classroom behavior during the treatment period; (3) ratings of the children's performance of standard prehensile tasks using both the experimental and old terminal devices; and (4) maintenance.

In the course of the studies the children were required to make four visits to the clinic servicing them, during a minimum period of five months. The procedures followed at each of these clinic visits are described below and the data-gathering instruments are presented in Appendix A.

1. First Clinic Visit: Screening

A screening session was conducted during the first visit. The children and their parents were oriented to the purpose of the survey, the number of visits required, and the need to follow through with the experimental procedures. Parents and children expressing a willingness to participate selected glove shades from shade guides provided by both manufacturers. Neither the experimental hand nor a complete cosmetic glove was shown to the patients or their parents during the first visit. Selection Form I was completed and sent to NYU-Child Prosthetic Studies.

The candidates were evaluated on the basis of information provided on the Selection Form and sampling requirements. Upon approving a candidate, New York University sent the clinic a hand and glove for the child and a Teacher Questionnaire (Form VI), to be completed by the child's classroom teacher prior to fitting of the experimental hand.

The Teacher Questionnaire pertained primarily to the child's psychosocial adjustment in the school environment. The teacher was asked to fill out the questionnaire on each child, before the experimental hand was fitted, and to complete a corresponding form at the conclusion of the study. The purpose of this procedure was to determine whether the child's behavior or prosthetic performance in school was affected as a result of wearing the experimental hand. In order to provide comparability of data, it was important that the same teacher provide both pre- and post-fitting observations.

2. Second Clinic Visit: Fitting

At the second clinic visit a prosthetic performance test utilizing the old terminal device was administered (Form II), and the reactions of children and parents to the former device were ascertained (Forms IIIa and IIIb). The child was fitted with an experimental hand and initial reactions to the new component were secured from child and parents (Form IV). The child and parents were then given instructions that the experimental hand was to be worn exclusively until the next clinic visit two months later.

3. Third Clinic Visit: Two-Months Post-Fitting Evaluation

Two months after the fitting the reactions of children and parents to the new component were again recorded at the clinic (Forms IIIa and IIIb). Comparisons between old and new terminal devices, with respect to weight, ease of operation and usefulness (Form IV) were noted and a prosthetic performance test, in which first the new hand and then the old terminal device were evaluated, was also conducted (Form II). The parents were then told to permit the wearing of either the old or the new terminal device, as the child desired, and were scheduled for a further clinic visit two months later.

4. Fourth Clinic Visit: Final Evaluation

The final evaluation was conducted four months after the initial fitting. The reactions of child and parent to the new hand were again obtained (Forms IIIa and IIIb) and the old and new devices were compared in the same manner as earlier (Form IV). The Clinic Summary Data Sheet (Form V) was recorded and a second copy of the Teacher Questionnaire (Form VI) was sent to the classroom instructor for completion.

RESULTS

I. SUBJECTIVE REACTIONS

A. Parent and Child Preferences

At the conclusion of the test period the 77 children participating in the study and their parents decided almost unanimously in favor of retaining the experimental hand, with only seven rejecting it completely. In contrast to these seven rejections, 21 children expressed a desire to wear the hand exclusively. The remaining 49 children took intermediate positions ranging from a predominantly-hand to a predominantly-hook preference. All in all, 42 children and their parents clearly preferred the hand; 15 were ambivalent or offered contradictory opinions; 20 preferred the hook.

1. Hand Used Exclusively

Of the 21 children (13 girls and 8 boys) who chose to wear the hand exclusively, 20 were prior hook wearers, one had previously worn a Becker Plylite hand, and one had never worn a prosthesis before because his parents had refused to accept a hook. Cosmesis was extremely important to this group and was often the only factor mentioned by the child.

JM, a long below-elbow amputee, who was 6 years 11 months old at the initiation of the study, is typical of the children in this category. When asked what he liked about the hand after four months' wear, he replied, "I like it-the way it looks." He disliked the appearance of the hook, and could think of nothing favorable to say about it, or anything unfavorable to say about the hand. The hand functioned better, he said, and was important to him for use at school. Schoolmates stared at first, but liked it. JM's mother thought he had better function with the hook, but only because he had not had the new hand very long. She also remarked that he should wear the hand all the time because "it gave him more confidence." The hook's only contribution was that it prepared the child for the hand, she said.

Sandra, a short below-elbow amputee, was 5 years 9 months old at the beginning of the study. She cited better function as her chief reason for preferring the hand: "...can move things better--holds lots of things better." She disliked nothing about the hand, liked nothing about the hook, and said that she wanted to wear the former all the time. Her mother preferred the hand for reasons both of appearance and grasp: schoolmates found it easier to hold on to when playing games, and it didn't slip when the child tied her shoes. Sandra should not wear a hook at her age, her mother declared.

2. Hand Used Predominantly

The hand was the terminal device of choice for an additional 21 children (15 girls and 6 boys). The hook was preferred for rough outdoor activities in which the glove might be damaged, or for specific activities in which hook function was superior.

Typical of the group was Curtis, age 5, a very short below-elbow amputee, who liked "everything" about the hand: it resembled his other hand, held paper still when he wrote, and grasped a baseball bat better. However, he felt that the hook was lighter, easier to open, and superior for playing with certain toys. His mother was pleased with the appearance of the hand, Curtis' attitude toward it, and the fact that other children were willing to hold it in games. However, she thought he should wear the hook at home for activities which might damage the glove. During the last two months of experimental wear, when parents and children could choose which device would be worn, Curtis used the hand exclusively, except when repairs were required.

Diana, age 5, a short below-elbow amputee, expressed a desire to wear the hand most of the time and the hook only for swimming (sic!). The reason for her preference was that "it looks like my other hand." Earlier she had found the hand somewhat harder to operate and had experienced difficulty releasing it from bicycle handles. Her mother was concerned about tears on the glove fingers, but Diana said, "It doesn't matter what the glove looks like." Her mother agreed that the hand should be worn in most circumstances, but thought the hook could be used for swimming, and as a replacement in case the hand broke.

3. Hand and Glove Used About Equally

Seven children (5 girls, 2 boys) and their parents desired to retain both hook and hand and to use them on an approximately 50-50 basis. For example, Carol, an 8-year-old short below-elbow amputee, who lived on a farm, preferred the appearance of the hand: "It gives me another hand and people don't stare;" and the function of the hook: "I don't drop things with the hook or worry that someone might bump into me and knock them out of my grasp." She also was concerned about tearing the glove. Carol chose to wear the hand both to regular and Sunday school and the hook for farm chores and play. Her father agreed with the child's viewpoint. He thought the glove not rugged enough, but the hook handy and sturdy.

4. Parent and Child Disagreement

There were eight children (6 boys, 2 girls) whose primary choice of terminal device differed from that of their parents. In five instances, the child chose the hand and the parent the hook; in the other three cases, the positions were reversed. The basis for disagreement was usually a difference of relative emphasis upon appearance and function.

Michael, age 6, whose partial hand amputation was fitted as a wrist-disarticulation, was pleased that the hand "looked like my other one", but acknowledged that the hook was lighter and easier to use. If he could retain only one device, he would choose the hook, since he could do much more with it; however, his mother and friends preferred the hand. The latter were sometimes afraid of the hook. Michael's father preferred the hand for cosmetic reasons and cited other advantages: "...more chance to play cowboy and wrestling ... children not afraid ... danger of bumping into others when playing with the hook."

5. Hook Used Predominantly

Six boys and seven girls preferred the hook for daily use and the hand for dress occasions. Five of the children were under 5 years of age (one age 3 and four age 4), and four of these had not yet attended primary school, kindergarten, or play school. Eleven of these children rated the hook function better and ten specifically said the hand was heavy or hard to operate; one older boy complained that the hand did not afford a tight grasp, and a younger girl said the hook held things in a better position. Parents of twelve of these children declared hook function was better; the other parent expressed no preference.

Danny, with an elbow-disarticulation and split-ray hand, was the youngest child in the study - barely 4 years of age when fitted with the hand. To open it he had to hold his elbow completely extended with maximum tension on the cable. Even in this position, full opening required more effort than he typically cared to exert, although he was pleased that the hand looked like his natural one. Danny stated that the artificial hand was heavier and harder to operate than the hook and did not pick up objects as well. The hook was better for grasping a swing chain and for holding his bread to push food. The child's mother hoped that his skill with the hand would improve, but after four months she reported that he wore it only for "going visiting." She thought the hand would be of greater use when he was older.

6. Hand Rejections

In view of the fact that complete rejection of the experimental hand was rare, it is interesting to note the instances when it occurred. Seven children rejected the hand completely; four of these were 4- or 5-year-old boys, one was a 7-year-old girl with bilateral shoulder-disarticulations, and the other two were a boy and a girl, both 9 years old, who were excellent users of their hooks and apparently were not concerned with the appearance of this device.

Various factors contributed to these rejections. Several of the younger boys and the 9-year-old boy and girl obtained better function with the hook and seemed relatively unmindful of appearance. The bilateral shoulder-disarticulation amputee was a marginal user of any prosthesis and found the increase in operating forces and the difficulty of positioning the hand without a wrist flexion unit intolerable. Three children experienced excessive hand malfunctions and two others, because of frequency of glove damage or difficulty in getting replacements, wore unsightly gloves for prolonged periods.

7. Age and Sex in Relation to Acceptance Level

The data contained in the last two categories of acceptance level (Hook Used Predominantly and Hand Rejections) suggest that age is a strong consideration governing hand or hook preference. Such a relationship would not be surprising, since younger children may be expected to: (1) experience difficulty with hand weight and operating forces because of limited physical development, and (2) be more careless in their use of device, less concerned with the niceties of appearance, and would not be subject to the social pressures of the school environment.

Age, however, cannot be regarded as an absolute criterion, since several of the children in the study who selected the hand as their primary choice were 4-year-olds. In fact, when the age and sex of the children are tabulated against indicated levels of preference (Table 2), we find that sex appears to be more significantly related to choice of device than does age. Thus, girls of all ages for whom the hand is of appropriate size appear to be potentially the best candidates for the No. 1 Hand, while younger boys would seem to be less likely to accept the device.

TABLE 2

RIGHT- AND LEFT-HAND WEAR PATTERNS

GIRLS (N = 44)										BOYS (N = 33)									
AGE WHEN FITTED WITH HAND											AGE WHEN FITTED WITH HAND								
TOTAL	4	5	6	7	8	9	10	11		3	4	5	6	7	8	9	10	11	TOTAL
13	1	4	4	2[a]	-	1	1	-	Hand Used Exclusively	-	1	1	2	2	2[b]	-	-	-	8
15	4	1	2	4	2	1	-	1	Hand Used Predominantly	-	-	1	1	1	2	-	1	-	6
5	-	1	1	1	1	1	-	-	Hand and Hook Used About Equally	-	-	-	1	-	1	-	-	-	2
2	1	-	1	-	-	-	-	-	Child-Parent Disagreement	-	1	1	1	1	2	-	-	-	6
7	2	1	2	2	-	-	-	-	Hook Used Predominantly	1	2	-	1	1	-	-	-	1	6
2	-	-	-	1	-	1	-	-	Hand Rejections	-	1	3	-	-	-	1	-	-	5
44	8	7	10	10	3	4	1	1	TOTAL	1	5	6	6	5	7	1	1	1	33

[a] Previous terminal device was Becker Hand; became a 100% No. 1 Hand wearer.

[b] No prosthesis used prior to hand; became full-time (or at least school-time) hand wearer.

B. Effects on School Adjustment

The Teacher Questionnaire was designed to secure pertinent information concerning the behavior of the child in school while wearing the old terminal device and the experimental hand respectively. It was hypothesized that the child's classmates and teacher might react more positively to a hand than they had to a hook and, as a result, adjustment of the child to the school situation would show discernible changes. This type of improved behavior had been noted previously when a child who had been a non-prosthesis wearer was fitted for the first time (6).

Historically, two significant problems frequently encountered by juvenile amputees wearing hooks to school have been: (a) being called "Captain Hook" and similar names by classmates; and (b) refusal by other children to hold their hooks in hand-holding games. Elimination or reduction of these difficulties was anticipated when the child was fitted with a functional terminal device that closely resembled a normal hand.

The teacher's opinion was obtained concerning various aspects of the child's school behavior: (a) attendance, (b) homework, (c) conduct, (d) friendships, (e) social participation and leadership, and (f) extent of use of the prosthesis. As provided by the study plan, a Teacher Questionnaire was to be completed twice: once while the child was still wearing a hook, and again after four months of hand wear, when the child would presumably have acquired sufficient skill in the use of the hand, and changes in school behavior would have had an opportunity to develop.

When it became apparent that a majority of the children in the Left-Hand Study would not have worn the hand for four months before the end of the 1961-62 school year, the original plan was modified to provide for completion of the second questionnaire just prior to the end of the academic year, regardless of legnth of time the hand had been worn.

Unfortunately, comparable hook-and-hand questionnaires (i.e., both completed by the same teacher) are available for only 16 of the 77 children in the sample. The majority of the remaining 61 children were of pre-school age or were fitted with the hand toward the end of the school year or during the summer, so that they did not have the same teacher at the beginning and end of the study. The Teacher Questionnaire data was, therefore, supplemented by information concerning school and personal adjustment from other sources, wherever available.

1. Reactions and Representative Comments

Of the 29 boys and 21 girls in the sample who were 6 years of age or over, 26 boys and 21 girls were either wearing the hand in school at the termination of the experiment or stated that they intended to do so when the Fall term began. Included in this group were four of the children whose preferred device was the hook. Nevertheless, they wore the hand to school. One boy, age 8, summarized the opinion of these four children when he said, "I wear it because the kids like it better."

As mentioned previously, a number of children reported that prior to using the hand they had been called "Captain Hook" by other children and that this had disturbed them. There is considerable evidence that the effects of this name calling can be quite destructive to social relations among children. One girl, in fact, refused to wear the prosthesis to school after such an incident. When the hand was worn, these difficulties tended to disappear. The essence of the reaction to and acceptance of the hand may be gathered from the large number of favorable comments made by playmates, schoolmates, teachers, and others.

Representative statements reported by the children included the following:

> "My schoolmates were excited about the hand because I have five fingers on the left hand now."
>
> "It smells nice, looks nice, and works nicer than the hook."
>
> "I like the feel of the hand; it looks real."
>
> "One little girl thought my hand had grown back."
>
> "They said it was pretty. The girls aren't scared of it."
>
> "I wanted to look at it. I always wanted to know when I was going to get it. It drives me out of my mind."
>
> "My school friends stared at first; they liked it."
>
> "At school they all liked the looks, especially how real it looked, including the fingernails."
>
> "Kids like to see the way I can bend the fingers (floaters) all the way back. They like to feel it. One boy bit it to see what it would do."

Representative reactions, reported by the parents, included these remarks:

> "They were surprised when they found out he could move the fingers and thumb."
>
> "Children in school were not aware of his prosthesis until he wore a short-sleeved shirt. They displayed curiosity and then seemed to be very casual."
>
> "In many cases the fact that it is not a natural hand has had to be brought to their attention, even when it was worn without long sleeves."
>
> "Danny will start school this Fall and the principal was amazed to see the hand. He said he had to look twice to make sure it was the same child. Danny's playmates were sure he had gotten a 'real' hand."
>
> "His friends are afraid of the hook. But with the hand, they will take hold of it and play games."
>
> "The child said she used to like the hook and wore it all the time, but now some of her friends don't like it and are afraid of it."
>
> "Her schoolmates noticed the change, and they completely accepted it. Her sisters were quite proud and anxious for their friends to see she had a new hand."
>
> "When he played games with other children, most of them were afraid to hold his hook. Since he's worn the hand they aren't afraid."
>
> "Cindy is happy about the better attitude of the children around her, especially in school."
>
> "She said that one of her best friends 'almost fainted,' she was so delighted to see her with two hands."
>
> "The appearance has done wonders for her at school."
>
> "The children at school crowded around him and asked to see how it worked."
>
> "Her friends had called her 'Captain Hook' (when she wore the hook). Little ones cried and would run away from her, afraid. We actually had to bribe her to wear the hook to school. Now we have no difficulty getting her to wear her arm with the hand all the time."
>
> "Children don't call him names ('Captain Hook')."

> "School children are delighted and fascinated with the hand."
>
> "...interested because it is different; want to see how it works. Betsy will show it."
>
> "It is easier to hold on to when playing games."
>
> "The change from the hook to the hand caused a lot of questions to be asked at first. But it was soon accepted."
>
> "Danny wore the hand every day for two weeks and some of his classmates were not aware that it was not his own hand."

Only a few children volunteered negative remarks:

> "His brother got scared of the hand, but later liked it."
>
> "Sister afraid of it at first."
>
> "Pammy (sister) thought it was a 'weirdy'."

2. Attendance, Preparation, and Conduct in Class

The teachers' reports concerning the children's attendance, preparation, and conduct in class yielded very little information of significance. Only one child (a triple amputee) was considered below average in attendance as a result of absences related to his prosthesis. The factors of preparation for class and conduct showed slight changes in ratings from the first to the second questionnaire, but there were no differences specifically attributable to hand wear.

3. Friendships, Participation, and Leadership

Ten of the 16 children for whom Teacher Questionnaires were available appeared to have achieved excellent to adequate adjustment and participation in class with both the hook and the experimental hand. Despite these satisfactory relationships, these children still found the appearance of the hand advantageous in the school setting as a means of decreasing social prejudice. Several of these ten children remarked that their classmates were now more willing to hold hands in games and seemed friendlier. This pattern of increased acceptance tended to enhance the self-concept of the children in the study.

Five children were reported as improved in class participation or friendships after being fitted with the artificial hand, although the prosthetic performance of two of this group was considered to have deteriorated. However, the improvement in appearance was obviously more important than the decrease in function. For this small group of children, regardless of their skill in or amount of hand usage, there was a discernible change in the type and extent of their social interactions. This took the form either of an increased number of social contacts with various children or of an improved relationship with one or two selected classmates.

An example of the personal importance attached to the hand is apparent in the report of one child's physical therapist, which describes his behavior after being fitted:

> "On the way back on the train, Randy patted his hand against his face and scratched the tip of his nose several times before settling down to sleep. Until then, he couldn't keep his eyes off it, and when he lay down, he put the hand on his chest 'for all the world to see.' As we neared Bloomington, he wondered if we shouldn't go by the school because 'perhaps Mrs. Sheveland (the teacher) will still be there.'
>
> "After dinner he put his prostheses on and toured the neighborhood to show everyone his hand. His mother reportedly was greatly pleased; so much so that she could not hold back the tears on more than one occasion during the evening, so that when Randy said his prayers, she had to leave the room. He wanted to wear his hand to bed but when his mother explained that it had to be put into the plastic bag, he accepted the explanation.
>
> "This morning he arrived at school in 'clam-digger' pants and a long-sleeved shirt. He had told his father yesterday that if he wore long-sleeved shirts no one would ever know his hands were not real."

Other examples of the significance of the hand follow:

> "The teacher said the boy is actually using the hand more than he had ever used the hook. (This was in spite of the fact that all reports indicated that his functional capabilities with the hook were greatly superior.) His mother said, 'We were very pleased that he had the hand for his first Holy Communion.'
>
> "The nun said Randy did not need to hold hands in prayers or going to and from the altar, since she thought this might be a difficult thing to do, but he did as the other children were doing and was very proud."

Another child, Sheila, had reconciled herself to the reluctance of other children to hold the hook:

> "Some children don't like to touch it (the hook), but I know a girl who has long fingernails and I don't like to touch her hands, either. When I first got it, I thought the kids in school will be surprised. They will think I don't belong in a crippled children's school!"

Another child, Philip, used his artificial hand to shake hands.

The last of the 16 children for whom data were available, a girl of 6, did not have a good relationship with her teacher or with the other children. There was no discernible improvement in the situation after she was fitted with a hand. Still, by the time of the second questionnaire report, she was somewhat more willing to display her prosthesis in public and make use of it.

4. Conclusion

Although there was no clear-cut evidence of widespread, dramatic changes in behavior attributable to the use of the APRL-Sierra hand, the data all point in the direction of improved self-perceptions, as well as of better social attitudes and relationships. With the exception of the 10 percent of the sample who rejected the hand for a variety of reasons, the remaining amputee children, their parents, teachers, and classmates reported a variety of positive social consequences related to hand wear. For the most part these reports referred to improved feelings, opinions, and attitudes of the subjects, although a small number of positive behavioral changes could also be documented. In general, the children themselves, as well as their classmates and parents, were socially more comfortable as a result of the introduction of the hand.

The functional limitations of the hand in comparison to a hook are documented in the next section of this report. In contrast, the evidence concerning the cosmetic benefits of the device, particularly its concomitant psycho-social implications, is most impressive.

II. HAND FUNCTION

In the study of the No. 1 Right Hand, which preceded that of the Left, the results of comparative performance testing indicated that there was little difference between the hand and the hook on the various test activities. Statements of children participating in the study (and of their parents) indicated a relatively high level of performance with the experimental hand, but advantages and disadvantages were not clearly defined.

These results appeared to be at variance with past clinical impressions, which indicated that a hand was a significantly less functional terminal device than a hook. Hence, in the Left-Hand Study the performance tests were repeated to check the results of the earlier study. An attempt was also made to delineate more completely the relative usefulness of the two devices by obtaining data concerning their effectiveness in a wide variety of activities.

A. Performance Tests

The specific test items used are illustrated on Plates IV to IX and fully described in Appendix I. The tests were typically administered by occupational therapists and the rating scale employed ranged from a score of 5 for performance approximating that of a non-amputee, to 1 for a performance in which the terminal device was not used, in accordance with the subjective criteria presented below:

Rating	Criteria
5 -	A nearly normal bilateral performance in which the terminal device seems essential, i.e., it is used to perform active functions in addition to and more advanced than holding, such as grasp and transportation and manipulation of the object.
4 -	A bilateral pattern in which the terminal device is a significant aid in grasping and/or hooking.
3 -	Terminal device used for occasional grasping only, alternating with passive use.
2 -	Terminal device used passively for pushing, weighting, or support, but not for grasp.
1 -	Terminal device not used, although elbow and forearm may be used as an aid.

Ratings of 1.5, 2.5, 3.5 and 4.5 were interpolated to indicate a performance whose quality was between two categories.

Six Performance Test Activities

Plate IV - "Kitty in the Kegs" Taking Apart and Re-Assembling Five Barrels

Plate VII - "Loony Links" - Assembling a Jointed Doll.

Plate V - Drying Dishes

Plate VIII - Cutting and Pasting

Plate VI - Putting on Clothes

Plate IX - Eating Ice Cream

Each child's performances with hook and hand were compared on the basis of best scores obtained while utilizing each device. In the Left-Hand Study performance times with each device were also obtained. The comparative data are presented in the tables which follow:

TABLE 3

COMPARATIVE MEAN PERFORMANCE RATINGS, HOOKS vs. HANDS, RIGHT- AND LEFT-HAND STUDIES

Activity	Right Hand (N = 32)		Left Hand (N = 36)	
	Hook	Hand	Hook	Hand
Kitty in the Kegs	4.23	4.05	4.42	4.00
Dry Dishes	4.06	3.62	4.19	3.60
Put on Clothes	3.45	2.77	3.83	2.94
Loony Links	3.87	3.75	4.01	3.46
Cut and Paste	3.58	2.87	3.95	3.03
Eat Ice Cream	3.16	2.72	3.35	2.68

TABLE 4

COMPARATIVE EFFECTIVENESS OF PERFORMANCE, HOOKS vs. HANDS, RIGHT- AND LEFT-HAND STUDIES

(N = 68)

Activity	Better Performance						Hook and Hand Equal			Could Not Do or Not Reported
	Hook			Hand						
	Right	Left	Total	Right	Left	Total	Right	Left	Total	
Kitty in the Kegs	7	17	24	2	1	3	23	18	41	0
Dry Dishes	13	16	29	5	2	7	14	17	31	1
Put on Clothes	16	23	39	2	0	2	13	12	25	2
Loony Links	6	19	25	4	0	4	22	17	39	0
Cut and Paste	16	24	40	4	4	8	12	6	18	2
Eat Ice Cream	15	17	32	3	2	5	14	16	30	1
TOTALS:			189			29			184	

TABLE 5

COMPARATIVE SPEED OF PERFORMANCE, HOOKS vs. HANDS, LEFT-HAND STUDY

(N = 36)

Activity	Better Performance		Hook and Hand Equal*	Could Not Do, or Not Reported
	Hook	Hand		
Kitty in the Kegs	25	8	3	0
Dry Dishes	26	7	2	1
Put on Clothes	23	10	1	2
Loony Links	24	6	6	0
Cut and Paste	17	3	15	1
Eat Ice Cream	26	9	1	0

There are obvious limitations to these data, in that the tests may have differed with individual children (the type of clothing donned, for example), and there were undoubtedly differences in the frames of reference employed by different therapists in rating a given performance. Since the data themselves are of doubtful precision, the application of tests of statistical precision is not indicated. Within these limitations, however, there is evidence that:

1) Mean performance ratings in all activities were higher for the hook (Table 3), which clearly appeared to be the better device functionally. Its superiority was most evident in the test activities of "Put on Clothes" and "Cut and Paste." The smallest differences in mean ratings were found in the "Kitty in the Kegs" and "Loony Links" tests. Both of these latter activities involve the grasping of objects for which the active fingers and thumb of the hand are relatively well-adapted.

2) In a total of 408 hook and hand performance comparisons, shown in Table 4 (68 children performing 6 activities with each device), hook performance was rated as superior in almost half the instances (189 times). Interestingly enough, however, hook and hand performances were rated as equal almost

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*The large number of equal-time scores, particularly for "Cut and Paste," represent an inability to complete the test with either device in the five minutes allotted.

as frequently (184 times), although hand performance was considered better in only a relatively insignificant number of cases (29). In this tabulation of the data also, the superiority of the hook appears less marked in the same two test items--"Kitty in the Kegs" and "Loony Links."

3) The comparative time data (Table 5) indicate that in the majority of instances hook performance was faster as well as more effective than hand performance, although again the results are by no means unanimous.

1. Right-and Left-Hand Differences

It is interesting to note (Tables 3 and 4) that in the Left-Hand Study the performance ratings more clearly reflected the functional superiority of the hook than was the case in the tests with the right hand. For example, only seven children of 32 were rated as performing the "Kitty in the Kegs" test better with the hook in the Right-Hand Study. In contrast, 17 of 36 children had better ratings utilizing the hook in this activity in the Left-Hand Study. A similar marked difference in comparative ratings is evident in the "Loony Links" task. In the other test activities, the differences diminished until in the "Eat Ice Cream" item the Right- and Left-Hand data are almost identical.

The reasons for these differences are not clear. The subjectivity of the rating scale may, of course, have been a consideration. However, since the trend of the data is consistent, i.e., favoring higher comparative hook ratings in the Left-Hand Study, it would appear that other than chance factors are operative.

Handedness might possibly be a factor, but unfortunately, data on this variable were not obtained in the study. It is also possible that in the prior Right-Hand Study the raters were affected by a "halo" factor which had diminished by the time of the later Left-Hand Study.

B. Functional Preferences

In studying child and parent opinions concerning the function provided by the No. 1 Hand in comparison to that available in standard hooks, the task is complicated by the strong emotional factors involved. In many instances the excellent acceptance of hand appearance clearly tended to influence the answers to questions concerning its function. In interpreting the responses of children and their parents, therefore, it must be borne in mind that the hand was almost three times as heavy as the hook previously worn by the children; and although operating forces to initiate opening were only somewhat higher than for the hook, the forces required to obtain full opening were significantly higher[*] -- two factors which should make use of the hand more difficult. Pertinent comparative data are presented in Table 6:

TABLE 6

WEIGHT AND OPERATING FORCES OF HAND AND HOOK

Terminal Device	Pinch (lbs.)	Weight (grams)	Operating Forces	
			To Initiate Opening (lbs.)	To Open Fully (lbs.)
No. 1 Hand	2	170-173	4 ± 1	9 ± 1
Dorrance 10X Hook:				
a) 2 Rubber Bands	2	62	3	3.5
b) 3 Rubber Bands	3	63	4	5.75

Thus, when children report, as some do, that the hand is lighter and easier to operate than the previously-worn hook, the data must be questioned. Nevertheless, conservative interpretation of the available information does provide insight not only into hand usage but also into terminal device function in general.

The presentation which follows is based primarily on data from the Left-Hand Study, but this is supplemented where appropriate by evidence from the predecessor Right-Hand Study.

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[*] Actual pinch forces in the hooks worn by the children in the study were not obtained. However, recommended forces for the age group are: Below-Elbow 3½ lbs., Above-Elbow 3 lbs.

All 39 children and parents in the Left-Hand Study were asked, "With which terminal device is the child able to perform more activities?" The answers were:

	Hook	Hand	No Preference
Children	18	14	7
Parents	16	9	14

However, two children and two parents in the No-Preference category added statements which suggested that the hook provided more function and that their No-Preference choice was motivated by a balance between hook function and the cosmetic appeal of the hand either to the child or parent.

Furthermore, some children who rated the function of the hand as better than that of a hook made comments indicating the reverse: Joseph - "The hand is heavier and harder." Robin - "The hand can do a couple of things but not too many things." Linda - "The hand is heavier and harder but I like the way it works." The therapist said that this girl's answer seemed influenced by a strong desire to keep the hand.

On the other hand, several children who preferred the function of the hand were able to back up their choice by specific examples: Susan, a young above-elbow amputee, said the hand was easier to don, better for washing dishes, for holding paper, and to pick things up; and Rodney, also an above-elbow amputee with an unfitted paraxial hemimelia (ulnar) on the contralateral (right) side, said the hand was heavier but easier to operate. His therapist said the hand did not afford Rodney greater function but he was much more eager to use it. This greater enthusiasm was also noted in Susan, the above-elbow amputee previously mentioned. The greater motivation to use the hand on the part of both these youngsters may have actually resulted in a higher level of functioning!

1. Relationship with Age and Amputation Level

Fourteen of the 39 children fitted with the No. 1 Left Hand reported it to be as heavy as or heavier than their hook, and 17 found it hard to open or otherwise more difficult to operate than their hook had been. There seemed to be a significant relationship here with age, as indicated by the fact that of 17 children, age 3 to 5, eight found the hand heavy, while of 22 older children, between the ages of 6 to 10, only six reported that the hand was heavy. Of those who stated the hand was difficult to operate, ten were in the 4 to 5 age bracket, only five in the 6 to 10 age group.

A relationship to amputation level was also apparent. The one shoulder-disarticulation amputee found the weight acceptable but the hand too hard to operate. He retained the hand, nevertheless, for cosmetic reasons. Of the five above-elbow amputees, four found the hand heavy and difficult to operate, and the remaining child rejected it after less than two months' wear. In contrast to these negative reports, two above-elbow amputees, only 5 years old, were among those who were most highly motivated to use the prostheses with the hand device.

The combination of youth and a higher level of amputation made the use of the hand much too difficult for the youngest child in the study, an elbow-disarticulation who was barely 4 years old when fitted. Consequently, at the conclusion of the study he was wearing the hand only for special occasions. Of the four wrist-disarticulation amputees, the two 4-year-olds found the hand a little heavy and difficult to operate, while two 8-year-olds advised that both weight and operating forces were satisfactory.

C. Specific Types of Grasp

In the Right-Hand Study a general comparison of the functional qualities of hand and hook, based on child and parent opinions, had yielded indecisive results. Therefore, in the Left-Hand Study children and parents were requested to rate the suitability of both the old terminal device (hook) and the No. 1 Hand, not only for grasping objects in general, but also for eleven specific types of grasp or activity areas. Explanatory comments concerning terminal device use for each specific function were also solicited.

The eleven activity areas were:

1) Carrying objects, such as school bags, purses, lunch pails, etc.
2) Grasping or picking up very small elongated objects, such as pins, paper clips, etc.
3) Grasping or picking up small elongated objects, such as pencils, scissors, etc.
4) Grasping paper.
5) Grasping or holding soft objects, such as sandwiches, toothpaste tubes, etc.
6) Grasping or holding drinking glass.
7) Using silverware while eating.

8) Grasping large bulky objects, such as paste jars, books, balls, etc.
9) Grasping objects such as bicycle handles, swing chains or ropes, etc.
10) Putting on clothes, such as shirts, blouses, etc.
11) Putting on shoes and socks.

Many of these areas involve the performance of a number of discrete activities. Hence, the data obtained not only provide bases for comparison of hand and hook functions, but also supply considerable general information concerning the activities of children with upper-extremity prostheses. Since this information may be of significance to prosthetic clinic personnel, especially to therapists and to individuals concerned with the development of devices for children with arm amputations, the data relating to each of the activity areas is presented in some detail.

1) Carrying objects, such as school bags, purses, lunch pails, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children (N = 39)	Hook	32	0	6	1
	Hand	21	4	8	6
Parents (N = 39)	Hook	34	0	3	2
	Hand	34	1	2	2

Approximately four-fifths of the children reported the hook as satisfactory for carrying objects with handles, while only half found the hand satisfactory. Parents, on the other hand, believed the hook and hand functioned about equally well for holding these objects. Where difficulty was experienced with the hand, it was usually because the objects carried were too heavy for the amount of "Bac-Loc" provided. Illustrative comments in this respect were:

Betsy - "The hand doesn't let me hold heavy things."

Linda's mother - "Buckets, lunch pails, and anything of metal or plastic that is heavy slips from her grasp."

Gabriel's mother - "The hand is satisfactory provided the handle is not too thick and the object not too heavy."

Plate X - Carrying a School Bag

2) Grasping or picking up very small elongated objects, such as pins, paper clips, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	23	4	9	3
	Hand	15	13	6	5
Parents	Hook	20	11	6	2
	Hand	12	16	10	1

More than half the subjects and parents rated the hook as satisfactory for picking up very small objects. The hand was considered adequate for this function by only about a third of the children and parents. Some children pointed out that the hand was satisfactory for holding very small objects but not for picking them up. One parent suggested that the child's vision was blocked by the rest of the hand, another that the floating fingers were in the way. Among the illustrative remarks made by children and parents indicating difficulties with this aspect of hand function were:

John - "nails but not pins"

Sean - "I can't pick them (small thin objects) up."

Susanne - "I have to hold the object in the other hand to pick it up."

Danny's mother - "too much effort and concentration"

Plate XI
Holding a Safety Pin

There were considerably fewer remarks indicating that the hand was considered adequate for such tasks.

3) Grasping or picking up small elongated objects, such as pencils, scissors, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	30	1	4	4
	Hand	26	7	2	4
Parents	Hook	32	2	4	1
	Hand	28	6	4	1

Three-fourths of the children and parents considered the hook satisfactory for this function, while a slightly smaller proportion also found the hand satisfactory. The objects given particular attention within this category of use were scissors, pencils, crayons, hammers, and put-together toys.

i) Scissors

It was apparently impossible to cut with ordinary scissors held in either a prosthetic hook or hand. Thus, unilateral amputees held scissors in their good hand, while bilaterally involved children could not use them at all unless the scissors were especially modified.

ii) Pencils

Reports were mixed, with some children rating the hook better for picking up and holding pencils, but with more subjects preferring the hand:

Jeff - "I can hold a pencil better with the hook."

Danny - "The hand holds a pencil better for sharpening."

Randy - "I can pick up pencils easier with the hand."

Plate XII - Holding a Pencil

Only one or two of the children with unilateral amputations made reference to writing with the prosthesis, although this was, of course, usually necessary for bilateral amputees. The weight of the evidence appeared to favor the hook for this task:

Gail - "I can write better with a hook."

Teacher of Randy (a bilateral arm amputee) - "He is more secure doing written work when he wears hooks."

iii) Hammers

There were only two references to hammers, one favoring each terminal device:

Danny - "The hook is better for using saws, hammers and things like that."

S.S. (girl) - comparing hand and hook: "I can't use a hammer with a hook."

iv) Put-together Toys

There were two statements, both favoring the hook:

Michael - "I prefer the hook for put-together toys."

Susan's therapist - "Susan does not use the hand for prehension in take-apart toys."

In summary, scissors appeared to be difficult, if not impossible, to grasp with either hook or hand, pencils somewhat easier to handle with the hand, and put-together toys easier with the hook, and possibly writing also.

4) Grasping paper

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	37	0	1	1
	Hand	30	4	1	4
Parents	Hook	34	1	2	2
	Hand	34	2	1	2

Nearly all children rated both the hook and hand as satisfactory, with only four rating the hand as unsatisfactory. Almost all of the parents considered both devices to be satisfactory.

The comments indicated that grasping paper was not one function but several, each calling for a different application of the terminal device. Involved were such tasks as holding paper for cutting with scissors, holding (weighting) paper on a table or desk for writing, picking up paper, selecting one sheet from many, holding playing cards for card games, etc.

i) Holding paper to cut with scissors

Two children cited "hold paper while cutting with scissors" to explain their rating of the hook as satisfactory, but in both cases they considered the hand also suitable for this purpose. The therapist of a third child (Susan) felt that the hand was less helpful: "When cutting paper, Susan usually places the paper in the hook", she declared. "With the hand, she seldom places the paper in the hand; it seems to crush the paper and hold it in an awkward position." Susan herself regarded both devices as satisfactory for grasping paper.

Plate XIII - Grasping Paper

ii) Holding paper on table or desk while writing

The hand was considered better for holding paper while writing:

Sean's mother - "With the hook the paper tends to slip; results in a ragged print."

Danny - "The hand holds down paper better for writing."

Gail's mother - "School paper work seems to be neater with the hand because the paper doesn't slip."

Plate XIV - Weighting Paper

iii) Picking up paper or selecting one sheet from many

Several remarks seemed to indicate that the hand was better for picking up paper, but one bilateral amputee mentioned difficulty in selecting one sheet from many:

William (bilateral upper) - "The hand is satisfactory to pick up one sheet of paper, but not to select one from many sheets."

Joseph - "With the hand it is easier to pick up papers and hold them."

However, two parents stated that their children did not use the hand to pick up paper, for example:

> Ronald's mother - "He grasps paper with the hand by transferring it from his good hand to the artificial one."

iv) Holding playing cards for various games

> Susan's therapist contributed the following: "Playing card games is an activity which is performed better with the hand. It is in a better 'holding' position and the cards come out easier when she is taking them from the hand."

5) Grasping or holding soft objects, such as sandwiches, toothpaste tubes, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	20	9	9	1
	Hand	13	10	12	4
Parents	Hook	21	10	5	3
	Hand	24	9	5	1

Half the children rated the hook as satisfactory, but the number dropped to a third for the hand. Half the parents considered the hook as suitable and a slightly greater number rated the hand as adequate. More children than parents reported that neither device was used for grasping soft objects.

Picking up and holding a tube of toothpaste apparently presented no problem, but difficulties arose with sandwiches, cookies, candy bars, marshmallows, grapes, or raw eggs, all of which were usually held in the sound hand. The majority of the children experienced difficulty in holding soft objects with either device:

> Debra - "The hook squashes it and I can't eat it . . . the hand squashes the sandwich."
>
> Joseph - "The hook might squash them; the hand can pick it up but I'll smash it."

There were some children who made comments favoring the hand:

> Danny - "With the hand I can get a sandwich better without squeezing it."
>
> Mother of Randy (triple amputee) - "Eating sandwiches is a treat which he was unable to do with hooks."

A larger number, however, preferred the hook for this purpose:

Thomas - "The hand pinches soft things, such as candy bars and sandwiches."

Thomas' mother - "The only complaint we have (against the hand) is holding soft objects."

Mother of Linda (hook) - "Raw eggs, marshmallows, and grapes are items she carries without mishap." (But this child did not use the hand for soft objects.)

Plate XV - Grasping a Sandwich

6) Grasping or holding drinking glass

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	8	8	18	5
	Hand	7	12	16	4
Parents	Hook	13	8	13	5
	Hand	12	11	15	1

Less than a fourth of the subjects rated either hook or hand as satisfactory for holding a drinking glass. The parents were slightly more positive, a third of them rating both hook and hand as suitable. Several of the children who gave a "satisfactory" rating explained that they would use a terminal device only to hold a glass by the rim when filling it with water or to carry it while setting the table.

Comparisons between hook and hand were few. Some children stated that the hand did not open wide enough for available glasses or that the glass slipped. Two others, however, stated that the hand had a better grip and did not slip. Small opening and slippage were problems also reported with hooks. The general impression is that even children who rated a terminal device as satisfactory for holding a drinking glass were merely claiming they could hold a glass, as a special feat, not as a commonly-used skill. Illustrative comments were:

i) Cannot open hook or hand wide enough

Connie (hook) - "Mother has no glass small enough."

Danny (hand) - "can't open wide enough to get around glass"

Sandra (hand) - "satisfactory "if it is a small glass"

Plate XVI

Grasping a Paper Cup

ii) Glass slips

Mother of Danny (hook) - "Does not use on glass . . . it is slippery . . . he is afraid he'll drop it"

John (hand) - "glass slips out"

iii) Glass might break; plastic glass better

William (bilateral upper) - with hook, "use plastic glass or coffee cup"

Linda (hook) - "I can do it OK, but we have no plastic glasses at home, so I don't try much."

iv) Holds by rim, with two hands

Susan's therapist - "does not hold it with experimental hand alone, but uses both hands."

Mother of Kathy (hook) - "will hold by the rim when filling"

Linda's mother - "Being normally right-handed, she uses the hook only when setting empty glasses on the table."

v) Uses cup with handles, drinking straw

Mother of William (bilateral arm amputee) - "With the hand he can use a cup with a handle well."

Randy (triple, wearing hooks) - "Usually I use a straw or a cup."

Mother of Linda (hand) - "cups with handles, not glasses"

Mother of Sandra (hand) - "good for cups only"

7) Using silverware while eating

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	13	2	22	2
	Hand	15	2	19	3
Parents	Hook	19	3	14	3
	Hand	21	2	16	0

Approximately a third of the children and half of the parents rated both hand and hook as satisfactory for holding silverware, while half of the children and a third of the parents indicated that neither device was used for the purpose. The slight differences favored the hand. With the exception of three bilateral arm amputees, the children who answered this question were left-arm amputees. It appears likely that they used the prosthetic device only for holding a fork while cutting meat, although one or two apparently held a spoon in the terminal device also. Many children, even some who regarded a terminal device as satisfactory, reported that the parents usually cut their meat for them.

Particular mention was made of problems of slippage, of difficulty of positioning, the better appearance of the hand performance, and the need for practice.

i) Some children had more difficulty with slippage when using the hook, but others had more trouble with the hand.

Plate XVII - Holding a Fork

John - "hook holds a spoon" but "with hand, fork kept slipping out"

Mother of Randy (triple, fitted bilaterally with hand) - "Randy is able to hold a fork or a spoon much easier; they frequently slipped out of hook."

ii) There was also some difference of opinion on the relative ease of positioning the hook and hand.

Susan's father - "She seems able to position the hand better than the hook."

S. Mc's mother - "The angle of the hand opening is excellent . . . for fine work and for eating the hand was excellent."

Randy (triple, fitted bilaterally with hands) "when we go out to eat sometimes I can't get the hands in the right position."

iii) The appearance of the hand in holding silverware was considered better.

Suzanne - (What do you like about the hand?) - "cutting meat; the way it looks"

iv) A few comments mentioned the need for further practice.

Christine - "I can hold the fork with the hook to cut meat; it is hard because I need practice."

Robin's mother - "hand is satisfactory, but she needs to learn skill."

8) Grasping large bulky objects, such as paste jars, books, balls, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	30	4	2	3
	Hand	18	12	3	6
Parents	Hook	32	2	2	3
	Hand	28	6	4	1

Three-fourths of the children rated the hook as satisfactory, but only half found the hand so. The same proportion of parents rated both hand and hook as satisfactory.

The intention of the question was to determine if the smaller (than hook) opening provided by the hand was a disadvantage in actual use. The specifications of the No. 1 Hand require that a minimum full opening of 2 inches be attainable with the thumb in the wide-opening position, although most hands exceeded the specification to a maximum of approximately 2-3/8 inches. However, there were indications that several children utilized the small (1½ inch) opening only and did not bother to change the thumb position. A Dorrance 10X Hook, by comparison, provided a 3-inch opening and the Dorrance 99X Hook a 3½-inch opening.

A number of children and parents specifically mentioned holding baseball bats, balls, paste jars, books, boxes, dolls, dixie cups, and a see-saw:

i) Baseball bats were better held by the hand.

Curtis - "With the hand, I can hold the bat better when I play ball."

Glenda's mother - "bats ball using both hands now"

ii) The hook was superior for throwing balls, but the hand was satisfactory for catching them in two-handed fashion. In general, the children found it difficult to grasp balls with either the hook or the hand.

Plate XVIII

Holding a Large Ball

Randy (triple amputee fitted bilaterally with hands) - "can throw farther with hooks"

Ronald's mother - "can play ball and catch it with both hands"

Danny (hand) - "only a little ball, but it doesn't work so well, either"

Suzanne (hand) - "tried a ball and it slipped out" (She did not use either device for holding balls.)

Rebecca - "hook better for practicing volleyball"

iii) The hook was somewhat better for holding paste jars.

Betsy - "hook holds large paste jar, dolls, and boxes better"

Danny - (hand unsatisfactory for large objects) - "only for paste jar and small books"

iv) Books, boxes, Dixie cups and dolls, if large, were better held with the hook, but one boy said riding a see-saw was easier with the hand.

Danny - (hook very satisfactory) "for holding checker box and song book" but uses hand "as helper only"

Betsy - "hook holds dolls and boxes better"

Plate XIX - Holding a Doll

Christine - "easier to hold Dixie cup with hook than with hand"

Danny - "can ride see-saw better with hand"

9) Grasping objects such as bicycle handles, swing chains or ropes, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	34	1	2	2
	Hand	24	3	7	5
Parents	Hook	36	1	1	1
	Hand	33	2	2	2

Most children and parents rated the hook as suitable, but some children stated that the hand was unsatisfactory or not used for these activities. Confusion may have existed because of the separate uses; several of the children played on swings but did not ride a bicycle or tricycle. The hook was more often preferred for holding a swing chain, but preferences were evenly divided for riding a bicycle. Several parents felt that the hand grasp appeared more natural. There was concern about the danger of tearing the glove or breaking the thumb of the hand on a swing chain. Other activities mentioned under this heading were climbing monkey bars and holding a jump rope, a broom and a hoe, or a bow for archery.

i) The hook was better for swing chains.

Rebecca - The hand slips on the chain and makes her grasp insecure. She uses the hand less on the chain of a swing because she is "afraid it will break the thumb of the hand".

S. S. - "Her hand lets go of rope when she is swinging high."

Susan's mother - "child seemed to use the hook more as a pusher for support or holding and uses the hand more in grasping. For example, she 'hooked' hook on swing chain, but holds it well with her hand."

However, Susan, at the conclusion of the study, used the hook for swings because of concern over glove damage: "Her father padded the chains of the swing but she still had large tears in the gloves."

ii) For riding a bicycle or tricycle, the preferences were evenly divided between hook and hand.

Jeff - "can ride bike better with hand"

Linda's mother - "She has learned to ride a bicycle since having the hand."

S. S. - "hand slips off the bike handle"

S. Mc's therapist - "hook better for larger, grosser activity, such as riding a tricycle, and for playground equipment"

Plate XX

Holding a Bicycle Handle

iii) The hook was regarded as superior for monkey bars and miscellaneous playground equipment.

S. S. - "I can't open the hand wide enough, even with thumb, to hold onto the bars at school."

Rebecca's mother - "On all outdoor playground equipment the hook seems to work best."

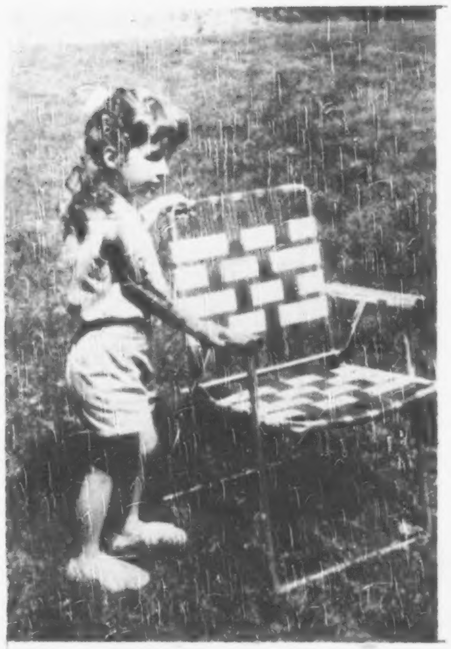

Plate XXI

Holding the Arm of a Chair

iv) There was some difficulty reported in holding a jump rope with the hand, and some individuals mentioned holding a broom and a hoe, and a bow for archery.

Debra - "When my hand holds a jump rope it sometimes tangles about my arm."

Danny - "hand holds a broom better"

Danny's mother - "It is important to wear hook for hoeing or cutting grass."

S. Mc's therapist - "Shooting a bow and arrow is done better with the hand. The bow fits nicely in the hand, whereas with the hook it slips."

Plate XXII

Holding a Jump Rope

10) Putting on clothes, such as shirts, blouses, etc.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	27	1	8	3
	Hand	21	3	9	6
Parents	Hook	29	2	6	2
	Hand	30	1	7	1

Two-thirds of the children and parents rated the hook as satisfactory, but only half the children considered the hand suitable for this purpose. Several children who regarded both devices as satisfactory commented that they were usually dressed, or were assisted in dressing, by their mothers. There were more comments favoring the hook than the hand; the glove tended to stick to cloth and there was glove discoloration attributed to contact with clothing, particularly from red dyes. Some of the illustrative remarks were:

i) Glove sticks to clothing.

William - "glove would stick to cloth"

Susanne - "Putting on my coat, the coat stuck to my hand."

ii) Discoloration from clothing.

Jeff - did less dressing with the hand "because didn't want to get dirty".

iii) Difference of opinion.

Mother of Randy (triple, fitted bilaterally with hands) - "Dressing is Randy's biggest problem with the hands."

Danny - "I can get pants on better with the hand."

11) Putting on shoes and socks.

		Satisfactory	Unsatisfactory	Does Not Use	Not Reported
Children	Hook	24	3	9	3
	Hand	19	3	11	6
Parents	Hook	29	3	6	1
	Hand	28	3	7	1

Two-thirds of the children and parents rated the hook as satisfactory, but less than half of the former considered the hand satisfactory. A fourth of the children stated that they did not use either device to put on shoes and socks, and the number who did not tie shoelaces with the prosthesis was undoubtedly much higher. Timothy, for example, said that he did not know how to tie shoe laces and that his mother dressed him, but he and his mother rated both devices as suitable for putting on shoes. Another reason given for parental assistance was that the child consumed too much time in dressing himself.

i) Some children preferred the hand.

S. Mc's therapist - "Susan ties laces better with the hand."

Danny - "The hook puts holes in my socks."

Plate XXIII - Dressing

ii) However, more preferred the hook.

Sean - (What do you dislike about the hand?) "The shoelaces slip out."

Sean's mother - "He could never tie shoes with the new device because of gripping the area of the finger tips only."

Debra - (What do you like about the hook?) "I can tie my shoes and do more things with it."

Carol's mother - "She can tie her laces better and faster with the hook."

12) Conclusions

In spite of the wide differences in the opinions expressed by the children and parents participating in the study, it was apparent that:

1) The APRL-Sierra Model No. 1 Hand was heavier, and in most instances more difficult to operate than the previously-worn hook, but for the majority of subjects in the sample these were not serious drawbacks. Those with shoulder-disarticulation amputations, and to a lesser extent some of the younger children and above-elbow amputees, were most likely to have difficulty with weight and operating forces. It is obvious, of course, that if the hand were lighter and had a more efficient operating ratio, it would be more acceptable to all.

2) The hand provided somewhat less pinch force than most of the hooks, and a less precise grasp. The majority of children reported that they could perform more activities better with the hook; however, many could also specify a number of activities that were performed better with the hand. The latter was preferred somewhat more often for tasks such as picking up a pencil, grasping paper, and holding silverware for eating. The majority of the children and their parents considered the hand as "adequate" to "very satisfactory" for a wide range of activities.

III. DURABILITY AND MAINTENANCE

A. Hand Problems

1. Right Hand

Because of a variety of mechanical problems encountered in the early stages of the Right-Hand Study, a decision was reached in October 1960 to modify the original test hands and refit them to the subjects in the study. A total of 30 "used" hands was involved. These modifications included the elimination of glove-cutting edges as well as the strengthening of the floating-finger attachments and the spring mechanisms of the thumb.

In April 1961, the manufacturer produced 16 new No. 1 Right Hands which incorporated all the modifications effected in the original model as well as a raised cable exit (3/64" higher than before). The majority of these hands were subsequently fitted to subjects in the study.

A total of 42 "modified" hands was fitted. Ten of these had one malfunction during the study, two had two malfunctions, and 30 had none. However, in many instances the period of observation following the fitting of the modified hands was brief.

Eleven of the 39 children fitted with the No. 1 Right Hand wore only one hand throughout the experimental period. Nine of these were modified hands worn through the four-month period, while two were original hands rejected during the course of the study. Twenty-two children wore two hands (usually one original and one modified), four had three hands, and two had four.

For purposes of recording and analyzing the data on malfunctions, the No. 1 Right Hands used in the study were divided into three categories: (1) original hands (unmodified); (2) original hands (modified); and (3) new modified hands.

In the analysis an attempt was also made to distinguish between malfunctions attributable to hard usage (external causes) and those resulting from deficiencies in design or manufacture (internal causes). In several instances, of course, one factor was superimposed on the other, e.g., some thumb malfunctions were apparently caused by the effect of rough use on a faulty thumb spring. The pertinent data are summarized in Appendix B, Part I.

2. Left Hand

Five of the 58 APRL-Sierra Model No. 1 Left Hands received by New York University were transferred to other research groups, leaving 53 to be used in the study. All the left hands were essentially identical to the modified right hands produced in the later stages of that study. Twenty-nine of those utilized in the evaluation have functioned satisfactorily (22 for four months or longer, 7 for shorter periods), but 24 became inoperative in the course of the study and had to be replaced at least once.

Twenty-two of the 39 children included in the report did not experience hand malfunction during the course of the experimental period (4 months or longer), but eleven required one replacement hand, and six needed replacements on two occasions. The detailed data on malfunctions of the left hand are presented in Appendix B, Part II.

3. Discussion

As described in detail in Appendix B, the principal malfunctions of both right and left hands were: (1) cable fraying or breaking; (2) rough cable action or jamming of finger mechanism; and (3) malfunctioning thumb. The unmodified right hands also exhibited a high incidence of loose or broken floating fingers. However, the change in method of attachment to the handshell and the change of material from rubber to silicon almost completely eliminated these difficulties.

Backlash was present in many hands returned for other repairs. In most instances this was easily corrected by the adjustment provided in the hand. Only three hands had essentially uncorrectable backlash and in these the adjustment screw had been broken during attempted manipulation. There were also several cases of damage to the handshell or movable fingers, generally due to falls on cement or similar rough usage.

a. Frayed or Broken Cables

The wrist units worn by most children in the sample (Hosmer WE-200) were too large for the No. 1 Hand; consequently the cable and housing bent sharply at the point of exit from the hand, contributing to fraying and eventual breakage of the cable. In the design of the No. 1 Hand, dimensions were based upon several studies of children's hand sizes; but, unfortunately, there was apparently no attempt to relate the base dimension to the commercially available wrist units.

In the modified right hands, and in all left hands, the cable exit was raised 3/64" in comparison with the original design. It was believed that further raising of the exit would pose serious cosmetic and manufacturing difficulties. However, even with this modification the hands were fully compatible only with an infant-sized wrist, e.g., Hosmer WE-100 (outside diameter 1-1/8"), but not with the Hosmer WE-200 or Sierra 215 (outside diameter 1-1/2") wrists typically fitted to children ages two through nine. It was recommended that a rubber spacer be used to alleviate the cable bend in fitting the hand to a WE-200 or larger wrist. However, this palliative was not universally applied and in any case hands so fitted subsequently developed fraying of the cable. Two or three prosthetists were able to replace cables which had broken or pulled out of the hand. However, this was a tedious and time-consuming operation and it would be most desirable if the attachment could be simplified to allow routine cable replacements.

b. Jamming of Finger Mechanism or Rough Cable Action

Jamming of the finger mechanism or rough cable action was generally attributed to water, dirt, powder, or other foreign matter entering the hand. The development of holes in the glove doubtless contributed to this problem. All hands repaired by Sierra were cleaned and oiled; many required replacement of rusty screws and pivot pins. In one case in the field, a local prosthetist examined a hand in which both thumb and finger mechanisms were inoperable, and discovered that the hand lubrication had combined with the powder used to don the glove to jam both mechanisms. He cleaned the hand and it subsequently worked satisfactorily. There was also one report of temporary jamming of the hand mechanism caused by the cable housing being screwed too far into the handshell. This was corrected by simply unscrewing the housing.

Malfunctions caused by foreign matter entering the hand might be reduced by eliminating the use of powder in glove donning, keeping the hand out of water, and changing to a hook when the child plays in dirt or sand.

c. Malfunctioning Thumb

There were various types of thumb malfunction: (1) jamming of the thumb caused by entry of foreign matter (see above); (2) jamming of thumb in closed position, caused by a burr. Inspection of one hand revealed that the smaller of the two cutout grooves of the rotating cam in the thumb joint had developed a burr, which prevented the spring-loaded wedge from sliding out of the lock hole and consequently prevented the thumb from opening. It was suggested that the lip radius of the smaller cutout groove might be increased in order to diminish stresses developed by the wedge. (3) inability to lock in the closed position, caused by the spring-loaded wedge slipping out of the thumb-boss detent. At the time of the Right-Hand Study this was believed to result from a sharp blow, a sudden severe jar, or some other shock condition. A recommendation was made that the thumb spring be more securely attached to the thumb post.

Thumb malfunctions continued to be a problem in the Left-Hand Study. APRL discovered that the thumb boss had been sheared away in one hand, either because of an excessive load on the thumb, or because the notch was not deep enough to carry normal loadings. The manufacturer expressed concern that the original design might be at fault, that the notch was indeed not deep enough and could not be made deeper without increasing operating forces. Subsequently, APRL determined that with proper fitting of the thumb-detent pin to the notch in the transfer washer, it would take a force of 42.6 lbs., applied perpendicularly to the thumb tip, to shear the thumb-boss detent notch.

However, there was a reduction in contact area and therefore in shear strength when the notch in the transfer washer was not properly aligned with the notch in the thumb boss. None of the three transfer washers examined by APRL had notches that were alike or aligned properly. It is obviously necessary that particular care in the alignment of the thumb mechanism be taken by the manufacturer. Repair of this particular type of thumb malfunction usually involved only a "reworking" of the thumb mechanism. However, in two instances the manufacturer considered it necessary to replace the entire handshell at considerable expense. He wrote, "The thumb boss is an integral part of the handshell casting. It therefore cannot be replaced or adjusted when worn, without replacing the entire handshell." **(Letter from Sierra Engineering Company dated February 19, 1963)**

B. Glove Problems

1. Durability

It is clear that the single most serious technical shortcoming of the APRL-Sierra No. 1 Hand-and-Glove combination was the lack of durability and stain resistance of the glove. Reports of gloves developing holes and discolorations after a short period of wear were common, from the initial fittings of the original, unmodified right hands, through the completion of the Left-

Hand Study. Early in the study, several clinic personnel and parents observed that the first holes appeared at the proximal, dorsal, interphalangeal joints of the middle and index fingers. They suggested that sharp edges on the hand, or friction from contact with the moving parts in the fingers, might be responsible. The mother of one child wrote:

> "The glove wore right through on the knuckle of the second finger and the steel shows through. It is also worn quite badly on the inside of the hand. It seems to be wearing wherever there is steel."

Another clinic gave the following report on a glove worn by a girl for six weeks:

> "At this time we noticed a worn place in the glove in the index finger at the proximal interphalangeal joint, due to a sharp edge at the joint in the hand. This hole is probably due to weather, sand, and Florida climatic conditions, and will result in deterioration of the joint. If the gloves are going to perforate at this point frequently, I think we should have an extra glove with the family at all times to replace the worn one, and thus save the mechanics of the hand from breakdown."

In September 1960, it was the consensus that a great deal of the excessive glove wear was due to sharp edges and prominences on the hand. All the participating clinics were advised to cover the sharp edges on the palmar surface of the first two fingers with a layer of pressure tape. At a meeting of the Subcommittee on Children's Prosthetics Problems in Grand Rapids on October 14, 1960, modifications in the hand were agreed upon. These included the following provisions to lessen excessive glove wear:

a) Elimination of protrusions at the interphalangeal knuckles of both moving fingers

b) Rounding or covering sharp edges on the palmar aspect of the proximal phalanx on both moving fingers

c) Rounding the edges of the handshell at the base of the moving fingers

The above modifications were subsequently carried out by the Sierra Engineering Company (provision b was met by covering the palmar aspect of the proximal phalanx of the moving fingers with a plastic boot) and the first modified hands were received by New York University in November 1960. All right hands received after that time and all left hands incorporated these modifications, but the gloves continued to deteriorate at a rapid pace, with much of the wear occurring at the proximal dorsal interphalangeal joints of the two moving fingers.

In both the Right- and Left-Hand Studies, clinics were requested to report the dates of all glove changes and to return damaged gloves to New York University, together with any information available on the causes of stain or damage. Although holes were sometimes reported after only a few days' wear, the majority of the children continued to wear their gloves until the damage was severe. In addition, the customary procedure for securing a glove replacement (child taken to clinic, letter from clinic to NYU requesting glove, NYU shipment of glove, child taken to clinic to obtain new glove) resulted in a further lengthening of the wear period.

Thus, in the Left-Hand Study the actual wear period per glove ranged from a low of 22 days per glove for a 5-year-old girl to 152 days for a 7-year-old girl, and averaged 67 days per glove, or slightly over two months. The boys, as might have been expected, were harder on gloves, averaging 60 days, as compared with 73 days for the girls. The following table also indicates that younger children were more severe on gloves than older ones:

TABLE 7

DURATION OF GLOVE WEAR, IN RELATION TO PATIENTS' AGES

N	Age	Mean Wear Period (Days per Glove)
11	3, 4	60
6	5	63
7	6	73
6	7	77
6	8	69
3	9, 10	76

a. Sites and Causes of Damage

Examination of the damaged gloves indicated that the single most frequent location of holes continued to be at the dorsal proximal interphalangeal joint of the middle finger; in some gloves there was a long, open rip from the proximal interphalangeal joint to the end of the finger. Many hands had a large hole inside the base of the thumb and a corresponding hole on the facing surface of the first finger. Many holes were noted at the tips of the thumb and moving fingers, at the nail of the first finger, and to a lesser extent at the nail of the second finger. In many instances, the parents could not supply any details regarding the cause of damage and simply stated that it had occurred as a result of normal daily activities. Several parents and therapists, however, were able to give specific information, and a fairly reliable impression of the principal causes of damage were obtained from their reports.

Holes at the proximal interphalangeal joints of the first and second fingers, at the tips of thumb and fingers, and at the backs of nails were apparently caused by the child hitting the hand against objects, or in some cases, merely leaning his weight on the hand while playing on the ground or the floor. The following comments were typical of many in the same vein:

> "The holes on the dorsum of the fingers probably came from his crawling on the floor and the ground while playing, and sometimes crawling up the stairs. Also, he balances himself on that hand while playing on the floor."

Plate XXIV
Holding a Baton

> "The damage was caused by walking on all fours while playing 'animal' and/or allowing the hand to drag along the wall."

> "The middle finger hit on a rough wall."

> "The mother states that the tear on the middle finger is a result of the child hitting her hand on the sidewalk while playing hopscotch."

> "Middle finger scraped, probably from picking up and throwing gravel, a favorite neighborhood practice at the present time."

On the other hand, the large holes inside the base of the thumb and corresponding long, open holes on the inside (palmar-ulnar) surfaces of the index finger were apparently caused by holding handles of bicycles or tricycles, or grasping swing chains:

"Most of the damage on this last glove was caused by the handlebars of her bicycle, which she learned to ride after receiving the second glove. The points of wear showed up on the thumb and index finger first, and later the index finger was nearly worn off."

"It was again torn primarily by the chains of the swing."

"The mother had no special comments relative to the damage of the glove - other than bicycle riding, accidental falls, etc."

"You will notice that thumb, index and middle fingers are badly battered. I attribute this to her falling off her bike onto the gravel in the driveway. She does ride her bike much better with the hand. She uses the hand just as much as the hook but it (the glove) doesn't take the wear and tear of play. She forgets that it will be torn."

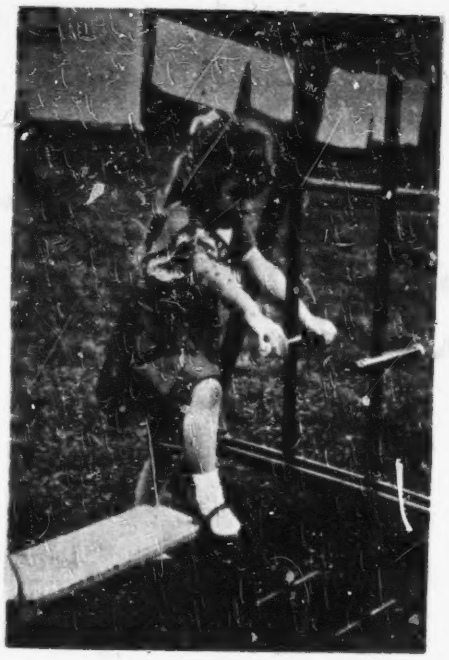

Plate XXV

Holding Seesaw Handle

Other glove damage was attributed to specific accidents:

"The patient fell, causing a tear in the middle finger."

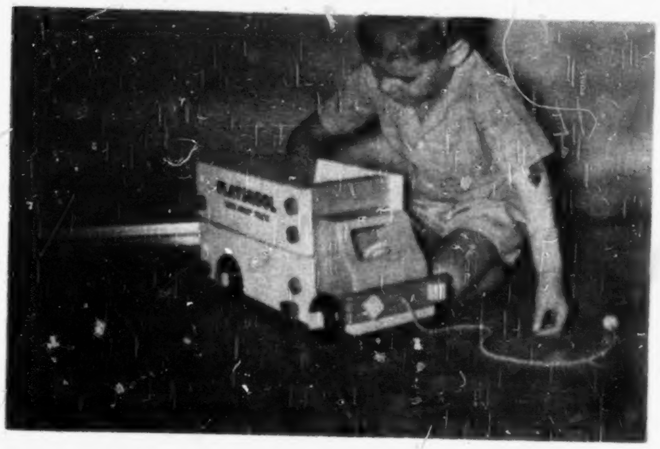

Plate XXVI - Resting Hand on Floor

"The slit in the palm of the glove occurred when Tommy was running downhill. He fell and his hand struck a rock."

"It was torn on a barbed-wire fence."

"The tear between the ring and middle fingers is where a little boy at school pulled on the ring and little fingers. The tear on the middle finger is where he kept hitting it on different objects."

"The hole in the index finger was cut at school while he was cutting construction paper to make a project."

"I tried to discover the reason for the loss of the covering at the nail area on the index and long fingers. I believe he chews or picks on them."

In general, holes, tears, cuts and abrasions of various kinds occurred in the gloves for the No. 1 Hand more frequently and in a shorter wear-period than is typically the case with hands worn by adults. This high incidence of damage is doubtless attributable to the fact that the normal daily activities of children include many that are particularly harmful to gloves, such as grasping bicycle handles and swing chains, banging the hand on the floor and ground, and falling. At the conclusion of the experimental wear period, several children wore the hand to school, but changed to a hook for play. However, this did not constitute a complete separation between activities "easy" and "hard" on gloves, since considerable rough outdoor play may occur during recess periods.

b. Glove Discoloration and Staining

The rapid tearing or wearing through of the glove material was not the only problem. In addition, most gloves developed a yellow or orange discoloration on the "rub-off" areas (tips of fingers, outside edges of thumb and little finger and, to a lesser extent, on the backs of fingers). Many had additional local stains, some were extremely dirty, and all were darkened with wear. Also, many gloves exhibited small areas in which the inside pigmented layer of the glove had worn off.

Yellow or orange discoloration was found on the "rub-off" areas of 34 of a total of 54 discarded gloves; of these, 23 were on the 27 gloves worn by girls. The colors varied from yellow to red-orange and the intensity from a faint, shiny yellow to an extremely bright yellow-orange. They were also very sticky, with nails of a lacquered or candied shininess on two gloves. These discolorations were apparently caused by the hand rubbing against clothing. In one case a red-orange discoloration was specifically attributable to the child rubbing her hand against a red jumper. The fact that the gloves worn by girls were more likely to discolor than those used by boys would seem to indicate that the brighter colors preferred by girls might be a factor, or perhaps they are more avid users of crayons and paints.

There were many small marks and stains on the returned gloves, but in all cases these were incidental to more serious damage. Among these were very small blue marks, probably ink; blue-purple staining and general discoloration, attributed by the mother to contact with the school desk and the use of crayons; a white speckled appearance at the tips of the fingers, of unknown origin; a yellow stain, caused by mustard; and a reddish-brown stain on the backs of fingers, possibly caused by the boy leaning his hand on his shoe when playing with trucks on the floor. A few gloves worn by boys were extremely dirty, which suggests that juvenile resistance to hand-washing may apply equally to the prosthetic hand.

There was also considerable depigmentation, a wearing off of the pigmented layer inside the glove. This resembled a light blue-grey stain, and perhaps for this reason was not often mentioned specifically by the mothers. The areas affected and the probable causes of damage were:

1) Depigmentation on the gauntlet, especially at the end of the glove and in streaks around the wrist area:

> "The pigment rubs off above, where it contacts the cable and the socket."
>
> "The mother believes the damage to the glove (color worn off in the gauntlet area) is a result of frequent interchange between the hand and the hook."

2) Depigmentation around the edges of holes and tears, occasionally in streaks down the length of a finger with a hole at joint or nail. Penetration of dirt through the hole probably aggravated this depigmentation.

3) Depigmentation inside the base of the thumb and inside the facing surface of the index finger, in splotches on the palm (particularly near the base of the ring finger), and to a lesser extent on the palmar surfaces of the fingers. This was apparently caused by rubbing against a bicycle handle or other grasped object.

Virtually all damaged gloves returned for inspection were found to be darkened. The causes were not ascertained; it was suspected, however, that some discoloration occurred with long exposure to air. It was also not determined if the various methods of cleaning gloves (mild soap, glove cleanser, frequent versus infrequent washings) had differential effects. Many children washed the cosmetic gloves at the same time they washed the sound hand, and some said they wore the hand when washing and drying dishes.

2. Solutions to Glove Durability Problems

In both Right- and Left-Hand Studies the lack of durability of the cosmetic gloves was the major cause of concern. As previously indicated, in at least one instance rapid glove deterioration contributed to the ultimate rejection of the hand, and in many cases it resulted in the child wearing the hand less than full time.

Furthermore, there were indications that the problem of glove deterioration was regarded rather more seriously after the conclusion of the study, when replacement gloves were no longer supplied gratis by the research program,and clinics and families became responsible for supplying these replacements themselves. For example, at the four-month check George chose to wear the hand at all times, but especially at school. Shortly thereafter, George's clinic made inquiries about the procedures followed by other clinics in paying for gloves: "Our budget is always low, but we will try to find the funds if that is the usual policy with other corresponding clinics." In the final teacher report on George, received after this date, she stated:

> "George had worn his hand every day until his last trip to the clinic. He has worn his hook ever since he came back. He informed me that he was 'saving the hand for good'. The hand was so perishable that after a few days he had it marked or torn."

In another clinic, Cheryl, age 6, elected to wear the hand exclusively, at the conclusion of the experimental period. One month after termination of the study, her clinic wrote:

> "The present glove, which was applied about a month ago, was torn the first day or so . . . the tear being about 1/4" in length. This child has absolutely refused to use the hook, and when the hand was being repaired recently, during the two-week period while it was in New York, she refused to wear any prosthesis; at any rate, she refused to wear the hook. This emotional storm is unquestionably the result of the application of a hand which she has accepted totally, and this has led to hook rejection. It is the first instance where this has happened. We are going to try to alternate hook and hand in an effort to save the glove and the hand, so that the expense will not be too great. The hand would be reserved for social or dress wear. How successful this will be, or how traumatic it will be, I don't know."

The same clinic mentioned that another 6-year-old girl had with considerable effort been pursuaded to wear the hook at home, and added:

> "The question comes up in the minds of those of us who are running the clinics as to the future cost for the State Crippled Children Commission or for the parents, so far as glove maintenance is concerned."

Essentially, there are three approaches to the solution of the problem of too-rapid glove wear:

1) Reducing damage opportunities or sources.

   a) The clinic can instruct the child to restrict wear of the hand to occasions less likely to cause glove damage, or to exercise care of the glove; that is, to use the hand less intensively during the period when it is worn. This solution did not appeal to many of the children. For example, one 7-year-old boy was unenthusiastic about the hand because "he had to be too careful with it when playing." It is clearly not a preferred solution.

   b) The parents can attempt to reduce sources of glove damage in the child's environment. However, it would be impossible to control all such sources of damage. For example, one father padded the chains of his daughter's swing in an attempt to eliminate wear on the inside of the thumb, the forefinger, and the palm of her glove. It is not known if this eventually succeeded in preventing or lessening damage from the child's own swing, but this is a very limited approach to the solution of the glove problem.

2) Reducing the contribution of hand hardness to glove damage.

When the hand strikes an object, supports the child's weight, or tightly grasps swing chains and the like, the glove material is compressed or jammed between two hard materials -- the external object and the handshell or fingers -- as in the jaws of a vise. If one of the materials were resilient, damage would presumably be reduced.

Thus efforts might be made to smooth and soften the outer material of the hand in order to lessen the effect of these impacts. One of the considerations in the choice of a soft material for the floating fingers was that of glove preservation, and the Army Prosthetics Research Laboratory now has a "resilient" hand under development. However, it will doubtless be some time before this is ready for general application or its efficacy as a glove "preserver" is evaluated.

3) Increasing the strength and stain resistance of glove materials

This is the line of approach which has received the most attention in the past decade, with the focus primarily on gloves for adult amputees. To date, two principal lines of development have been investigated:

a) Increasing the thickness of gloves of standard (vinyl) formulations

b) Experimentation with various other formulations designed to increase wear and stain resistance while maintaining adequate flexibility

a. "Overthickness" Gloves

The standard commercially available vinyl glove is of 35 mils thickness. Earlier (1956) attempts were made to use thicker gloves (40, 45 and 50 mils) with adult amputees. These efforts met with some success, so far as improved durability was concerned, although stain resistance was unaffected.

In the No. 1 Hand Study a further attempt was made to use thicker gloves in a somewhat desperate effort to reduce the high incidence of glove damage. Since May 1962, gloves supplied by the Kingsley Manufacturing Company for the child-size hand have been of 40 mils thickness. It is believed that this extra thickness may have contributed slightly to durability, and no complaints have been received concerning an increase in operating forces.

In June 1962, a glove of 45 mils thickness was tested on the hand of a 5-year-old boy known to be hard on cosmetic gloves. He noticed no difference in the forces required to operate the hand. However, after two weeks of wear, the glove had a hole in the middle finger and after five weeks' use it had to be replaced. The mother, however, felt that the experimental extra-thick glove had worn much better (sic!).

b. Changes in Glove Materials and Formulations

For many years (since 1957 and earlier), the Army Prosthetics Research Laboratory has experimented with various glove materials and formulations. The problem appears essentially to be one of improving durability and stain resistance while maintaining adequate flexibility, so that the glove will not interfere with hand function nor increase operating forces excessively. The two desired sets of characteristics are apparently not fully compatible.

i) Dilaminar Vinyl Gloves

These gloves embody an outer layer of plastisol formulated for stain and tear resistance, and an inner layer of a more flexible plastisol formulation. Nine series of vinyl dilaminar gloves have been developed in an attempt to find the optimal balance between stain and tear resistance on the one hand, and flexibility on the other.

These gloves have been tested by New York University, principally with adult patients, but with two limited series tried on children. The results indicate that the more highly durable and stain-resistant models are too stiff, particularly in cold weather. Formulations with adequate flexibility are less durable, but appear to be superior to the "standard" glove.

ii) Acrylate Gloves

The first acrylate gloves, of dilaminar construction, were tested in 1961 and found to have good stain resistance but to be deficient in flexibility. Weaknesses in wear qualities were also evident. A later version of the acrylate glove was a composite model consisting of a double layer of acrylate latex bonded to a seamless dacron base. A unique feature of this glove was that the color was bonded between the two layers of latex. These gloves proved to be highly stain resistant but they were also deficient in flexibility and tear resistance.

In summary, it may be said of the various possible methods of improving glove durability and stain resistance:

1) Restriction of use, and/or management of the environment appears of limited value, but these are the most effective means of prolonging glove life available at the present time.

2) Softening the exterior of the hand holds promise theoretically, but the actual effectiveness of this means of glove preservation will not be known until a "resilient" hand is available for testing.

3) Thicker gloves (40 mils) seem to improve durability slightly without deleterious side effects. Gloves for the No. 1 Hand could apparently be made in this thickness routinely. The application of still thicker gloves (45 mils) might be studied further.

4) One or more of the dilaminar glove formulations tested appear slightly but definitely superior to currently available vinyl gloves.

5) Acrylate and composite gloves are still in a relatively early stage of development.

Unfortunately the improvement in glove durability and stain resistance, which may be effected by items 2 to 5 above, appears on the basis of past experience to be relatively slight, while the problem seems to demand a glove with a significantly longer service life than that of the present item.

IV. PRESCRIPTION CONSIDERATIONS

A. Size of Sound Hand and Age

For the purposes of the Right-Hand Study, the No. 1 Hand was hypothesized as being appropriate for child amputees between the ages of 4 and 10. Consequently, experimental wearers were selected on the basis of this age range, rather than of size. In the course of the study, however, it became apparent that the hand was undersized for many of the children selected.

The clinics were then requested to report the following dimensions in all cases of noticeable size discrepancy: (1) circumference at the metacarpal-phalangeal knuckles, excluding the thumb, with hand in "closed" position (5-7/8" on the No. 1 Hand); and (2) length from the styloid process of the radius to the tip of the thumb (3-5/8" on the No. 1 Hand). Several clinics also reported hand dimensions of children for whom the No. 1 Hand was considered of appropriate size.

The following table presents the measurements of sound hands of children in the Right-Hand Study for whom the No. 1 Hand was (1) too small; (2) small, but acceptable; and (3) well-matched, according to the opinion of the clinic personnel:

TABLE 8

ADEQUACY OF NO. 1 HAND IN RELATION TO NATURAL-HAND SIZE

(N = 21)

	Size of Sound Hand		Age When Measured		Sex
	Circumference (In Inches)	Length	Years	Months	
No.1 Hand too small; prescription contra-indicated.	*	*	12	7	M
	(bilateral)		11	7	F
	7-5/8	4-3/4	11	1	M
	7-1/2	4-1/2	10		F
	6-7/8	4-3/8	6		F
	6-5/8	4	8	1	F
No.1 Hand smaller than sound hand, but acceptable.	7-1/4	4-1/2	9	9	M
	6-5/8	5	9	4	F
	6-1/2	4-3/8	9		F
	6-1/2	4	6	11	F
	6-1/4	4	9	1	F
	6-1/8	3-7/8	5	10	M
		3-3/4	9	5	F
	6-1/2		7	7	F
	6		9	3	M
	6		8	9	M
	6		7	5	M
No.1 Hand "matches" sound hand.	6-1/4	3-1/2	6		M
	5-1/2	3-7/8	5	7	M
	5-3/4	3-1/4	7	8	F
			4	4	F

* Data not reported

It would appear difficult, therefore, to derive a precise range of sound-hand sizes or ages for which the No. 1 Hand provides an acceptable match. In one case, where the sound hand was 6-5/8" in circumference and 4-1/2" in length, the clinic rated the hand as unacceptably small; but in another instance it was considered suitable for a child whose hand was 7-1/4" in circumference and 4-1/2" in length. It should also be noted that while the majority of the "oversized" children were 8 years of age and older, several younger children also fell into this category. Furthermore, even hands regarded as unacceptably small by the clinics were retained by the children and worn, at least for dress, for several months longer.

In the selection of candidates for the Left-Hand Study, dimensions of the children's sound hands were taken into consideration. In general, an effort was made to accept as wearers only those children with a sound-hand circumference of not over 6-1/4" and a length up to 3-7/8". It was also anticipated that the majority of such children would fall into the age range of four to eight years. As a consequence there were few complaints about size in the Left-Hand Study.

Christine, age 10, had sound-hand dimensions of 6-3/8" circumference and 3-7/8" length at the time of selection. These became 6-1/2" and 4-1/2" by the time of the four months' check and the clinic was then of the opinion that the hand was too small. Christine and her parents agreed, but strongly preferred even a poorly-matched hand to the alternative of a hook. There were six other children in the sample with sound hands of excessive circumference or length, i.e., larger than 6-1/4" in circumference and/or 3-7/8" in length. There was indication that all the children in this group were not completely satisfied with the size of the No. 1 Hand, but their lack of enthusiasm was generally expressed in the comment, "a little small, but still all right."

Thus, as a general guide in considering the prescription of a No. 1 Hand, it is possible to state:

1) For children whose remaining hand dimensions do not exceed 6-1/4" in circumference and 3-7/8" in length, the No. 1 Hand can probably be fitted without objectionable size disparity. Naturally, the closer children are to this level when fitted, the faster they will outgrow the No. 1 Hand.

2) Children with these hand dimensions will typically fall into the age range from large 3-year-olds to small 8-year-olds, with a predominance of 4-6-year olds. However, considerations of hand weight and operating forces may exclude some children at the lower end of this age range.

B. Clinic Opinions

Clinic opinions concerning various aspects of the No. 1 Hand were obtained in both phases of the study. Clinic personnel were also asked to express themselves on the question: "Are there any contraindications to prescribing this hand (age, sex, performance, etc.)?" Responses, however, were confined primarily to the experiences of the particular child under observation as each questionnaire was completed. Hence the comments made were essentially confirmatory of information gathered from other sources.

Expressions of a general attitude toward prescription and use of the No. 1 Hand were relatively rare. Thus, it is possible that the typical reaction of the clinics participating in the study was one of reservation concerning the experimental item-- of not wishing to take a strongly positive or negative position until more experience had been acquired and "all the returns were in".

This situation reflects the fact that the majority of the clinics participating in the program appeared to be "functionally oriented", some of them strongly so. Hence, a device which historically and in fact provides lesser function was likely to be viewed with scepticism. Some clinics were also concerned about the initial cost of the hand and glove and the expense of repairs and replacements, particularly of the glove.

If this interpretation of the prevailing frame of referance is correct, such comments as were made concerning "contraindications to prescription" take on added significance by their infrequent occurrence. To cite the Left-Hand study data again: For only nine of the 36 children discussed was dissatisfaction with some aspect of the hand strong enough to be mentioned as a possible contraindication to use. These instances were:

No. of Children	Contraindications
2	Discrepancy in size
2	Frequent breakage or malfunction
2	Force requirements excessive for particular child
1	Functional limitation as compared to hook
1	Rapid wear of glove a possible contraindication for a very active child.
1*	Emotional difficulty

---

* One clinic felt strongly that prescription would be a dubious practice where cosmesis was highly important for child and parent, if the next larger hand size was unavailable later.

Excerpts from a letter written by one of the clinic chiefs might be appropriate as a summary statement of prescription considerations. His comments not only reaffirm reactions to the hand which appear to have been fairly typical, but also express an approach to prescription which seems to be conservative yet reasonable:

> "The mother's comment with regard to cosmesis is that the hand is 'beautiful'. She is perfectly willing to go to all extremes in cosmetic appreciation. The mother feels that the child's reaction to the appearance of the hand was one of 'being proud of it'. This was exemplified by the child's desire to always wear the hand at school. It was interesting to me that, after approximately six months of wear, Debra was anxious to wear the hand all the time and not to use the hook any more. However, in the recent episode, when the hand became no longer functional, she was perfectly agreeable to return to the use of the hook. This is particularly interesting to me, because the mother feels that Debra actually lost no function in the transition from the hook to the hand.
>
> "At age 6, Debra learned to operate the thumb adjustment and, as a consequence, was able to continue with the prosthetic hand as the assisting side at school in such functions as holding a book while reading, so that she could turn the pages with her normal hand; holding papers while writing; and holding papers while cutting. At home, she was able to hold fork and knife with the prosthetic hand but, at age 7, is still able to cut only soft meat, such as a hamburger. She uses the hand in all bimanual activity.
>
> "Our own opinion here is that we will prescribe this hand for children who are already using a hook. In the unilateral case where there is reasonable dexterity, I feel that, with the prosthetic side being the assisting side, we can sacrifice the minimal loss of function which one probably gets in the transition from hook to hand. The only criticism is the amount of force necessary to operate the hand."

SUMMARY

The findings from the study of the APRL-Sierra Child Size No. 1 (Right and Left) Hand are presented in this report. The experiences of 77 children are described, including 38 subjects fitted unilaterally with the right hand, 38 fitted unilaterally with the left, and one child fitted bilaterally. All children discussed in the report wore the experimental hand for a minimum of four months, except for seven subjects who rejected it prior to completion of the wear period planned for the study.

The overall age range of the sample (at the time of fitting) was from 4 years to 12 years 4 months. All levels of upper-extremity amputation (prosthetic type), from wrist-disarticulation to shoulder-disarticulation, were represented. The one child fitted with both right and left hands was a bilateral below-elbow amputee.

Although the Right- and Left-Hand portions of the study were not conducted concomitantly, for the most part the findings were consistent and may be summarized jointly. They were:

I. OVERALL ACCEPTANCE

Less than 10 percent of the children in the study rejected the No. 1 Hand completely. The response of the remaining 90 percent ranged from highly enthusiastic to lukewarm. Actual (and planned future) wear of this majority group varied from exclusive full-time wear to part-time use primarily for social occasions. Cosmesis was the prime factor influencing the generally high level of acceptance. However, in the majority of instances cosmetic appeal was supplemented by an adequate degree of function.

Weight reduction and an improved operating efficiency (ratio of pull-to-pinch forces) would doubtless add to the acceptability of the No. 1 Hand. Both these improvements should be feasible.

II. SCHOOL BEHAVIOR

Evidence from teachers, parents and children emphasized the importance of the school environment to the child. The school milieu emerges as perhaps the most critical social setting in which the child functions.

Wearing the No. 1 Hand brought no revolutionary changes in school attitudes or behavior. Nevertheless, there was evidence that hand wear made a generally positive although variable contribution to the child's self-confidence and to the acceptance of the child by his peers and/or his teacher.

III. APPEARANCE OF HAND

A. Hand Design

The children participating in the study (and their parents) were almost unanimous in expressing a high measure of satisfaction with regard to the shape configuration of the No. 1 Hand.

B. Hand Size

The size of the No. 1 Hand was satisfactory, or at least acceptable, to the majority of the children in the study. It was too large for very few children, but too small for a large number, either initially or as a result of normal growth. This problem of undersizing, however, would be obviated by the availability of a larger hand (No. 2) to provide a size continuum.

Children whose normal hand size approximated that of the experimental item, or came within acceptable limits, typically fell into the 4- to 8-year-old bracket.

IV. GLOVES

In a number of individual instances, mismatching of shades was evident. In general, however, the coloring, tones, texture and fit of the cosmetic gloves used in the study were received enthusiastically by children and parents.

V. FUNCTION

The precise extent of usefulness of the No. 1 Hand in tasks typically performed by the children in the study was somewhat obscured by "halo" effects. However, the total evidence indicates that:

1. The No. 1 Hand provides less total function than the equivalent (Dorrance #10X) Hook worn by this age group of children.
2. The No. 1 Hand provides function equal to that of the appropriate hook for numerous activities.

3. The function of the hand was superior to that of the hook for some of the children in the performance of certain specific tasks.

VI. DURABILITY

A. Hand

Although the No. 1 Hand does not appear to be excessively fragile, malfunctions and breakages occurred with sufficient frequency in the course of the study to be cause for concern.

It appeared that in some instances causes of breakage could be reduced or eliminated by manufacturing measures. It was obvious, however, that a great deal of the damage was attributable to the activity habits of the wearers. Thus, it would be anticipated that if hands were used on an unrestricted basis, a fall or some other violence done to the hand, the entrance of dirt and/or water into the mechanism, etc., would result in ultimate breakage or malfunction.

B. Glove

The lack of durability of the gloves used in the No. 1 Hand Study was the prime negative feature in the entire investigation. It was apparent that the gloves available for the hand were not strong enough for the treatment meted out to them. Deficiencies in stain and discoloration resistance presented lesser problems.

VII. CONCLUSIONS AND RECOMMENDATIONS

The APRL-Sierra No. 1 Hand combines excellent appearance with a considerable degree of function. For many children, the hand's superior appearance offsets any functional inferiority to a hook.

Prescription of the No. 1 Hand may be considered for all unilateral, upper-extremity amputation levels from wrist-disarticulation to shoulder-disarticulation when the normal hand size does not exceed 6-1/4" in circumference at the metacarpal-phalangeal knuckles (excluding thumb) and length (radial styloid to thumb tip) does not exceed 3-7/8". This is true for both males and females.

The No. 1 Hand-and-Glove are relatively costly items. The initial cost, plus the expense and inconvenience of glove replacements and hand repairs, will undoubtedly tend to restrict purchase of the item. Manufacturing care to reduce potential breakage of hand parts and intensified efforts to develop a markedly more durable glove are recommended.

Because of possible limitations on hand usage related to glove and/or hand durability, it is recommended that concurrent prescription of a hook as a "spare" or "play" device be routinely considered.

Based on the results of the study, the No. 1 Hand definitely merits a place in the "armamentarium". Prior Interim Reports have recommended that steps be taken to make the No. 1 Hands, both right and left, generally available to prosthetic clinics. These recommendations are reaffirmed.

APPENDIX A

DATA-GATHERING QUESTIONNAIRES

I. SELECTION FORM

II. PROSTHETIC PERFORMANCE TEST FORM (RATING SHEET)

A. Performance Test Instructions (Activities)

IIIa. TERMINAL DEVICE RATING SHEET (CHILD)

IIIb. TERMINAL DEVICE RATING SHEET (PARENT)

IV. COMPARISON OF OLD AND NEW TERMINAL DEVICES

V. CLINIC AND MAINTENANCE SUMMARY

VI. TEACHER QUESTIONNAIRE

Child Prosthetic Studies
New York University

APRL-Sierra Hand Model #1 Field Test
Selection Form I

The patient referred to below is being recommended as a participant in the Model #1 Hand Field Studies. He meets the established selection criteria and Normative Survey forms have been completed for him and sent to New York University.

1. Child's name____ 2. Age__________

3. Child's Normative Survey Identification Number is____________________

4. Child's glove shade number: Kingsley____________
Prosthetic Services____________

5. This child, on the average, wears his prosthesis:

_____more than 12 hours per day
_____10-12 hours per day
_____7 - 9 hours per day
_____4 - 6 hours per day
_____3 hours or less per day

6. As compared to other children of the same age who wear their prosthesis approximately the same amount of time per day, this child actively utilizes the prosthesis:

_____much more than average
_____more than average
_____about average
_____less than average
_____much less than average

7. As compared to other prosthesis wearers of the same age, this child's skill in use of the prosthesis is:

_____much more than average
_____more than average
_____about average
_____less than average
_____much less than average

8. As compared to prosthesis wearers of the same age, this child's enthusiasm concerning prosthetic wear is:

_____much more than average
_____more than average
_____about average
_____less than average
_____much less than average

9. As compared to prosthesis wearers of the same age, this child's self-consciousness concerning his prosthesis is:

_____much greater than average
_____greater than average
_____about average
_____less than average
_____much less than average

(over)

10. If this child should reject the experimental hand, which of the following factors do you feel would be most responsible? Please base your opinion on your total experience with the child and his family.

_____weight of prosthesis
_____size of prosthesis as related to normal hand
_____durability factors
_____ease of function
_____other (Please explain)______________________________

____

____

11a. Circumference of the normal hand at the metacarpal-phalangeal knuckles, measured with the hand in the same position as the closed artificial hand.

_____ inches

11b. Distance from the thumb tip to the styloid process of the radius, measured with the hand held in the same position as the closed artificial hand.

_____ inches

____
Clinic Chief

____
Clinic

NOTE: Please do not permit the child or the parents to see the experimental hand or complete cosmetic glove prior to the time of actual fitting.

Child Prosthetic Studies
New York University

APRL-Sierra Hand Model #1 Field Test
Prosthetic Performance Test Form II

RATING SHEET

(Use separate sheet for each terminal device tested)

Patient's Name______________________ Age_____ Identification No.________

Clinic____ Date________

Performance Rated (Check One)

____Pre-Fitting Evaluation (Old Terminal Device), Type: ____________________)

____Two Months Post-Fitting (APRL-Sierra Hand)

____Two Months Post-Fitting (Old Terminal Device)

RATING SCALE

5	A nearly normal bilateral performance in which the terminal device seems essential; i.e., it is used to perform active functions in addition to and more advanced than holding, such as grasp and transportation and manipulation of the object.
4	A bilateral pattern in which the terminal device is a significant aid in grasping and/or hooking.
3	Terminal device used for grasping only intermittently with alternate passive use.
2	Terminal device used passively for pushing, weighting, or support, but not for grasp.
1	Terminal device not used, although elbow and forearm may be used as an aid.

Ratings of 1.5, 2.5, 3.5, 4.5 may be interpolated to indicate a performance whose quality is between two categories.

Record below the total amount of time that the child takes to complete the task and his performance rating for the task. If activity cannot be completed after 5 minutes, stop and rate as 1X, 2X, 3X or 4X, the X indicating inability to complete the task, and the preceding digit used to describe the type of performance as above.

			RATING
a. Unscrew and Reassemble Five Barrels (Kitty in the Kegs)	____Minutes	____Seconds	_____
b. Dry a Wet Cup, Saucer, and Dinner Plate	____Minutes	____Seconds	_____
c. Put on Shirt or Dress, Shoes and Socks	____Minutes	____Seconds	_____
d. Assemble Figure with "Loony Links"	____Minutes	____Seconds	_____
e. Cut Out and Paste Figure	____Minutes	____Seconds	_____
f. Eat a Dixie Cup of Ice Cream, Using a Spoon	____Minutes	____Seconds	_____

A. Performance Test Activities

All children participating in this study will complete the Performance Test at both the second and third clinic visits.

Materials

To obtain uniformity in the test procedures, the following toys and materials will be supplied:

"Loony Links" Toys
"Kitty in the Kegs"
Cup, Saucer and Dinner Plate
Spoon
Printed Figures, Colored Paper
Scissors and Paste

In addition to the materials listed above, a dixie cup of ice cream should be available for each test subject.

There should also be available:

An adjustable table or several tables of different heights to provide a test surface which is at least 4 inches below the lateral epicondyle (or prosthetic elbow center) when the test subject is standing.

A cloth dish towel for drying dishes.

A stop watch.

For the second test, both new and old terminal devices and possibly a hook-to-cable adapter to operate the old terminal device must be available.

Activities

1. Dis-assemble and Re-assemble Five Barrels ("Kitty in the Kegs") - This is a set of seven small plastic barrels, one inside the other. Only the five smallest barrels are to be used in the test. The child is asked to take apart the five barrels to reach the "Kitty" (picture of a kitten at the bottom) in the innermost barrel, and then to re-assemble the whole as before. Prior to the test the therapist should dis-assemble and re-assemble the barrels to insure that none of them is too tightly closed for the individual child.

2. Dry a Wet Cup, Saucer, and Dinner Plate (Plastic Dishes) - The child is presented with a wet cup, saucer, and plate. He is given a dish towel and asked to dry the dishes. Regardless of prior training, the test should be performed with the dishes held in the prosthetic hand.

3. Put on a Shirt or Dress (as appropriate) and Shoes and Socks - Starting with these items of clothing off, the child is asked to put them on. The therapist may assist the child in removing these garments before starting the test. Parents should be instructed to have the child dressed in shoes and socks.

4. Assemble a Jointed Doll ("Loony Links" - Kohner Brothers, No. 432)
   A pre-assembled doll is placed before the child and he is given the parts needed to assemble another doll: head, trunk, limbs, and feet. The child is then asked to assemble the doll and stand it on its feet.

5. Cut Out Figure with Scissors and Paste on Paper
   Each child will be given a piece of paper with a printed bear on it, a pair of scissors, a jar of paste, and a piece of colored paper. After the figure has been cut out, it should be pasted on the colored paper. The paste is easily washed off the glove.

6. Eat a Dixie Cup of Ice Cream Using a Metal Spoon
   The child is presented with a closed dixie cup of ice cream. He is to remove the lid and eat the ice cream (only three spoonsful; then the test is to be repeated). The therapist should remove the lid and replace it before the test starts. When the test is to be repeated with both terminal devices, the therapist should replace the lid carefully after the first performance to duplicate the original conditions. The consistency of the ice cream should be hard enough so that it will not drip off the spoon, but soft enough for the child to spoon it without difficulty.

Procedures

Except for the dressing activity, where sitting is required to don shoes and socks, all activities should be done while standing.

The Performance Tests should be conducted according to the following sequences:

1. Second Clinic Visit (with the old terminal device only) - Perform each of the six test activities in the sequence shown on the Rating Sheet (Form II). Complete the test before the child sees or wears the new hand.

2. Third Clinic Visit (using both the old and new terminal devices for each activity) - Perform all six activities with the new terminal device (hand) and record the total amount of time taken for each activity and the performance rating for the activity. Then install the old terminal device and repeat all six activities, again recording times and performance ratings in the appropriate spaces on Form II.

Child Prosthetic Studies
New York University

APRL-Sierra Hand Model #1 - Form IIIa

TERMINAL DEVICE RATING SHEET (CHILD)

(To be completed by therapist)

Patient's Name________________________ Date____________

Clinic________________________ Terminal Device____________

Fitting Visit ________ 2 Months Post-Fitting ________ 4 Months Post-Fitting________

Instructions: Listed below are certain characteristics and functions of terminal devices. Based exclusively on the best information you can obtain from the child, rate the terminal device for each of the listed characteristics or functions. The device should be rated for each function or characteristic in the space to the left of the descriptive phrase in accordance with the following code:

4 - Very satisfactory
3 - Satisfactory
2 - Unsatisfactory
1 - Very unsatisfactory
0 - Not used by child for this activity, although the device could conceivably be used.
X - No information available OR Not applicable

Please write in additional comments in regard to each function or characteristic whenever you feel they may be of value. Write these in the space to the right of each question.

Example: If the child feels that the color of the glove is satisfactory, but a lighter shade would be better, "color of the glove" would be rated as #3 (satisfactory) in the column to the left, and "would prefer a lighter shade" would be written on the right.

If the activity were "putting on shoes and socks" and the child has never attempted to use the device for that activity, although the device could be used for it - then 0 should be entered, since the child has no way of knowing how satisfactory the device is in respect to "putting on shoes and socks".

Remember - The ratings should reflect the CHILD'S opinions in regard to the terminal device, and NOT the opinion of the parents or therapist.

COMMENTS

____ 1. Grasping objects____________________

____ 2. Carrying objects such as school bags, purses, lunch pails____________________

____ 3. Grasping or picking up very small, elongated objects, such as pins, paperclips, etc.____________________

____ 4. Grasping or picking up small elongated objects, such as pencils, scissors, etc.____________________

____ 5. Grasping paper____________________

____ 6. Grasping or holding soft objects, such as sandwiches, toothpaste tubes, etc.____________________

____ 7. Grasping or holding drinking glass____________________

____ 8. Using silverware while eating____________________

(over)

Form IIIa
Page 2

4 - Very satisfactory
3 - Satisfactory
2 - Unsatisfactory
1 - Very unsatisfactory
0 - Not used by child for this activity, although the device could conceivably be used.
X - Unknown OR Not applicable. No information available.

COMMENTS

____ 9. Grasping large bulky objects, such as paste jars, books, balls, etc. ____

____ 10. Grasping objects such as bicycle handles, swing ropes, etc. ____

____ 11. Putting on clothes such as shirt, blouse, etc. ____

____ 12. Putting on shoes and socks ____

____ 13. Size of Terminal Device ____

____ 14. Shape of Terminal Device ____

____ 15. Weight of Terminal Device ____

____ 16. Overall appearance of Terminal Device ____

____ 17. Appearance of Terminal Device at wrist ____

____ 18. Initial effort required to open device ____

____ 19. Effort required to open device completely ____

RATE THE FOLLOWING CATEGORIES ONLY IF A COSMETIC HAND AND GLOVE ARE WORN

____ 20. Color of glove ____

____ 21. Texture of glove ____

____ 22. Durability of glove ____

____ 23. Stain resistance of glove ____

____ 24. Length of glove ____

25. General comments concerning function or appearance of terminal device:

TERMINAL DEVICE RATING SHEET (PARENTS)
To be completed by parent(s)

Patient's Name ______________________ Date ____________

Clinic ______________________ Terminal Device ____________

Fitting Visit ________ 2 Months Post-Fitting ________ 4 Months Post-Fitting ________

Instructions: Listed below are certain characteristics and functions of terminal devices. Rate your child's terminal device for each of the listed characteristics or functions, based on your own opinion. The device should be rated for each function or characteristic in the space to the left of the descriptive phrase in accordance with the following code:

4 - Very satisfactory
3 - Satisfactory
2 - Unsatisfactory
1 - Very unsatisfactory
0 - Not used by your child for this activity, although the device could conceivably be used.
X - No information available, OR Not applicable

Please write in additional comments in regard to each function or characteristic whenever you feel they may be of value. Write these in the space to the right of each question.

Example: If you feel the color of the device is satisfactory, but a lighter shade would be better, "color of glove" would be rated as #3 (satisfactory) in the column to the left, and "would prefer a lighter shade" would be written on the right.

If the activity were "putting on shoes and socks" and your child has never attempted to use the device for that activity, although the device could be used for it - then an 0 should be entered, since one has no way of knowing how satisfactory the device is in respect to "putting on shoes and socks".

IF YOU HAVE ANY QUESTIONS IN REGARD TO FILLING IN ANY OF THE BLANK SPACES, PLEASE ASK ONE OF THE CLINIC PERSONNEL FOR ASSISTANCE.

COMMENTS

____ 1. Grasping objects ____________

____ 2. Carrying objects, such as school bags, purses, lunch pails ____________

____ 3. Grasping or picking up very small, elongated objects, such as pins, paper clips, etc. ____________

____ 4. Grasping or picking up small elongated objects such as pencil, scissors, etc. ____________

____ 5. Grasping paper ____________

____ 6. Grasping or holding soft objects such as sandwiches, toothpaste tubes, etc. ____________

____ 7. Grasping or holding drinking glass ____________

____ 8. Using silverware while eating ____________

____ 9. Grasping large bulky objects, such as paste jars, books, balls, etc. ____________

(over)

4 - Very satisfactory
3 - Satisfactory
2 - Unsatisfactory
1 - Very unsatisfactory
0 - Not used by child for this activity, although the device could conceivably be used.
X - Unknown OR Not applicable. No information available.

COMMENTS

____ 10. Grasping objects such as bicycle handles, swing ropes, etc.____

____ 11. Putting on clothes such as shirt, blouse, etc.____

____ 12. Putting on shoes and socks____

____ 13. Size of Terminal Device____

____ 14. Shape of Terminal Device____

____ 15. Weight of Terminal Device____

____ 16. Overall appearance of Terminal Device____

____ 17. Appearance of Terminal Device at wrist____

____ 18. Initial effort required to open device____

____ 19. Effort required to open device completely____

RATE THE FOLLOWING CATEGORIES ONLY IF COSMETIC HAND AND GLOVE ARE WORN

____ 20. Color of glove____

____ 21. Texture of glove____

____ 22. Durability of glove____

____ 23. Stain resistance of glove____

____ 24 Length of glove____

25. General comments concerning function or appearance of terminal device:

Child Prosthetic Studies
New York University

APRL-Sierra Hand Model #1 - Form IV

COMPARISON OF OLD AND NEW TERMINAL DEVICES

____(Child)
____(Parent)

Patient's Name________________________ Identification No.__________

Clinic________________________ Date__________

Two-Month Post-Fitting__________ Four-Month Post-Fitting__________

	COMMENTS
A. Compared to old terminal device, the hand is: ____Lighter ____About the same ____Heavier	
B. Compared to old terminal device, operation of the hand is: ____Easier ____About the same ____Harder	
C. As compared to old terminal device, new hand is worn: ____More hours per day ____About the same ____Less hours per day	
D. As compared to old terminal device, new hand is worn: ____More days per week ____About the same ____Less days per week	
E. With which device is the child able to perform more activities? ____New terminal device ____No preference ____Old terminal device	
F. If more or less is being done with new hand, check areas in which there is increased (+) or decreased (-) performance. If performance is the same, write (0). If activity is not done with prosthesis, write (X). ____Eating ____Dressing ____Play ____Home Chores ____School ____Other	

(over)

	COMMENTS
G. For future use, would you prefer: ____New hand ____Old terminal device (hook) ____No preference	(Explain Preference)
H. List any comments made by others about the new hand, indicating which of the following commented: ____Brother ____Sister ____Schoolmates ____Others	
I. As compared with old terminal device, the care required by the new hand is: ____Greater ____About the same ____Less	
J. What do you like best about this hand?	
K. What do you like least about this hand?	
L. What do you like best about the old terminal device?	
M. What do you like least about the old terminal device?	
N. When do you feel it would be most important to wear the new hand instead of the old terminal device?	
O. When do you feel it would be most important to wear the old terminal device?	
P. If you could keep only one of the terminal devices, which would you choose? ____Old terminal device ____New terminal device	
Q. If you could keep both terminal devices (old and new) which would you use the most? ____Old terminal device ____New terminal device ____Both the same	

(To be completed by parents only)

	COMMENTS
R. How often do you clean the glove or hand?	
S. How do you clean it?	
T. Does the hand or glove now require replacement?	
U. Has the new hand been worn exclusively since the last two month visit? ____ Yes ____ No	
V. If NO, give estimate of time each has been worn: Old: ____% New: ____%	

Child Prosthetic Studies
New York University

APRL-Sierra Hand Model #1 Field Study
Clinic and Maintenance Summary - Form V

Clinic Summary

Patient's Name________________________________ Identification No.__________

Clinic________________________________ Date__________________

1. Is there anything about the size* or shape of this hand which you feel is unsatisfactory for this particular child (ratio of finger length to overall length, knuckle shapes, normal carrying angle, overall size)? ____________________

2. Has he had any problem in using this hand because of:
   - ____ a. Force required to operate
   - ____ b. Excursion required to operate
   - ____ c. Difficulty in operating the thumb
   - ____ d. Breakage or maintenance
   - ____ e. Other

   Please explain: ____
   ____

3. With respect to this child, do you feel that the cosmetic glove was:
   - ____ a. Satisfactory in all respects
   - ____ b. Unsatisfactory because:
     - ____ Poor color
     - ____ Poor resistance to stain
     - ____ Scratches, or wears through too easily
     - ____ Gets shiny or discolored too easily
     - ____ Problems in putting on clothing
     - ____ Other____
     ____

4. If repair or replacement was required for either the hand or the glove, please describe the problems, explaining how and when they arose and what was done to overcome them:
   ____
   ____
   ____
   ____
   ____
   ____

5. Are there any contra-indications for prescribing this hand (age, sex, size, performance, etc.)? If yes, explain________________________________

---

*If the size of the hand seems unsatisfactory, please remeasure and record on this form the circumference of the child's normal hand at the metacarpal-phalangeal joints excluding the thumb, and the length of the hand from thumb tip to styloid process of radius.

Child Prosthetic Studies
New York University

APRL-Sierra Hand Model #1 Field Study
Teacher Questionnaire - Form VI

Date____________________

Student's Name____________________ School____________________

Address____________________ Class____________________

ATTENDANCE

1. The child's attendance record is:

   ____Above average ____About average ____Below average

2. How many class days has the child been absent during the last three months? ____Days

3. Approximately how many of these absences have been as a result of factors related to the child's amputation? ________

4. Do the child's absences significantly interfere with his (her) classwork?

   ____Yes ____No.

FRIENDSHIPS AND GROUP RELATIONS

5. When not actually occupied in formal classwork he (she) is usually to be found in the company of: (Check one only)

   ____One particular classmate
   ____Several different classmates, but one at a time
   ____A particular group of two or three children
   ____A larger group of children
   ____Teacher
   ____Alone

   If none of the above apply, or if additional information is warranted, describe briefly: ____________________

   ____

6. Can his friends be characterized primarily as: (Check as many as apply)

   ____Girls
   ____Boys
   ____Older
   ____Same Age
   ____Younger
   ____Sportsminded
   ____Bullies or Rowdies
   ____Other - Explain: ____________________

   ____Shy and Retiring
   ____Good Students
   ____Average Students
   ____Poor Students
   ____Mischievous
   ____Leaders
   ____Children Without Other Friends

7. Have you appointed him to any class office of leadership? ____Yes ____No

   Explain: ____________________

   ____

(over)

8. Has he been elected by his class to any office of leadership? ____Yes ____No
Explain: ____
____

9. In temporary groups as for games, projects or committees, does he assume leadership on his own initiative? ____Yes ____No. If YES, what activities, and how frequently? ____
____

10. In temporary groups as for games, projects or committees, is he ever chosen by his classmates as a leader? ____Yes ____No. If YES, what activities and how frequently? If NO, explain: ____
____

USE OF ARTIFICIAL ARM

11. How often does he wear his artificial arm to school?
____Every day
____On an average of 4 days per week
____On an average of 3 days per week
____On an average of 2 days per week
____On an average of 1 day per week
____Never
____Explain: ____

12. Does he remove the artificial arm during the school day? ____Yes ____No.
If YES, please explain the circumstances. ____
____
____

13. Does he use the artificial arm regularly for most activities which require two hands?
____Yes ____No

14. Does he require any physical assistance in any aspect of school work?
____Yes ____No. If YES, explain: ____
____
____

15. If it were not for appearance, do you think he could get along in school as well without his prosthetic hand? ____Yes ____No

16. Do you think he could do more with his artificial arm in school? ____Yes ____No
If YES, explain: ____
____

IN ANSWERING THE FOLLOWING QUESTIONS (17-29), COMPARE THIS CHILD WITH THE NORM FOR HIS (HER) CLASS.

APPEARANCE

17. As compared with other members of his (her) class, the child's dress and appearance are:

____ Above average ____ About average ____ Below average

PREPARATION

18. How often does the child forget required school supplies, such as notebooks, texts, pencils, etc.?

____ More than average
____ About average
____ Less than average

19. How often are the child's homework assignments incomplete:

____ More than average
____ About average
____ Less than average

20. How neatly are the child's classroom and homework assignments done?

____ Neater than average
____ Of average neatness
____ Less neat than average

CONDUCT IN CLASS

21. In class the child is:

____ More attentive than average
____ As attentive as average
____ Less attentive than average

22. The child's behavior in class is:

____ Better than average
____ About the same as average
____ Worse than average

23. How sensitive is the child to criticism?

____ More than average
____ About average
____ Less than average

24. He (she) seeks attention in class by excessive hand raising, calling answers out of turn, boisterousness, etc.:

    ____ More than the average child
    ____ About as much as the average child
    ____ Not as much as the average child

25. The child complains about other children:

    ____ More frequently than average
    ____ With average frequency
    ____ Less frequently than average

26. The child complains about being treated unfairly:

    ____ More frequently than average
    ____ With average frequency
    ____ Less frequently than average

27. He (she) joins in class discussions:

    ____ More frequently than the average child
    ____ With average frequency
    ____ Less frequently than the average child

28. He (she) volunteers answers to questions:

    ____ More frequently than average
    ____ With average frequency
    ____ Less frequently than average

29. This child asks significant questions:

    ____ More frequently than the average child
    ____ With average frequency
    ____ Less frequently than the average child

Teacher's Name ______________________________

School ______________________________

Address ______________________________

APPENDIX B, PART I

MALFUNCTIONS OF APRL-SIERRA NO. 1 HAND (RIGHT)

N, Model	Description	Range of Wear (days)	External Cause	Internal Cause
14, original	Finger mechanism jammed, or rough cable action	28,37,49, 65,74,108, 133, 139, 161, 190, 216, 257, 300, 350	Six hands would not close completely.(specific cause unknown)	Thumb- and finger-drive springs displaced from normal operating position in one hand
			Probably caused by sharp blow	
			Sierra frequently mentioned replacement of rusty screws and pivot pins during repairs. (Water, dirt, other foreign matter entering hand probably important causes of jamming)	Vulnerability of hand to entry of foreign matter
3, original, modified		14, 137, 280		
1,new modified		61		
13, original	Thumb malfunction, (usually not specified as: "thumb sticks".One did not lock in close position,others jammed in closed position.)	47,65,74, 97, 108, 131, 144, 155, 161, 190, 216, 231, 300	Some thumb malfunctions precipitated by sharp blows or high forces	In one hand with thumb jammed in closed position, smaller of two cutout grooves of rotating cam in thumb joint developed burr.(This prevented spring-loaded wedge from sliding out of lock hole, thus preventing rotation.)
4, original, modified		44, 137, 153, 16		In two hands with thumbs not locking in closed position, spring-loaded wedge slipped out of thumb base cut-out. (Suggestion made at that time was to increase depth of cut-out or lengthen wedge to permit better locking; however,this would result in greater operating forces. Subsequently in Left-Hand study, it appeared likely that improper alignment of notch in transfer washer,with notch in thumb boss, caused latter to shear as result of forces encountered in daily wear.Repairs by Sierra included replacement of handshell (including thumb boss) in one hand and replacement of thumb detent in five. (Usually, thumb was merely "reworked".)

APPENDIX B, PART I (Cont'd)

MALFUNCTIONS OF APRL-SIERRA NO. 1 HAND (RIGHT)

N, Model	Description	Range of Wear (days)	External Cause	Internal Cause
18, original	Broken, detached or loose floating fingers	35,37,70, 72,74,97, 133, 144, 190, 216, 219, 225, 231, 257, 300,322, 324, 379	Routine wear.(In one case, roller-skating fall resulted in amputation of little finger.)	Method of attaching floating fingers to handshell inadequate on original model hands; satisfactory on modified hands. (Material of these fingers also changed from rubber to silicon.)
2,original, modified		29, 140		
5,original	Cable frayed or broken.(In two instances,cable pulled out of hand; on one hand, cable pulled out twice,but was repaired by local prosthetist.)	1,97,108, 139, 231	Use of WE-200 or Sierra 215 wrists (both 1½" outside diameter), or larger wrist units resulted in sharp bend in cable and housing.	Short-axis diameter of hand (1-1/8" to lower edge of cable housing exit) too small; raising of cable exit 3/64" (maximum possible without complete redesign of handshell) reduced problem slightly but did not eliminate it.
8,original, modified		14,47,71, 140, 147, 153, 213, 280		
1, new, modified		61		
16,original	Backlash (secondary to other malfunction in all but one hand)	300	Backlash present in numerous hands returned for repair, but probably adjustable by usual method. (In one hand in which backlash was cited as primary malfunction, prosthetist was unable to correct it because of stripped Allen screw.)	
5,original, modified				
1,original	Cracked handshell	108	Cause unidentified	
1,original	Dented removable plate	216	Cause unidentified. (secondary to other malfunction)	
2,original, modified		46, 213		
1, original	Axis pin at metacarpal-phalangeal joint backed out.	71		Improper staking of pin

APPENDIX B, PART II

MALFUNCTIONS OF APRL-SIERRA No. 1 HAND (LEFT)*

N*	Description	Range of Wear (days)	External Cause	Internal Cause
12	Thumb malfunction (Usually thumb would not lock in small opening position.)	1, 12, 20, 26, 59, 61, 63, 69, 83, 86, 87, 175	One thumb broken while child was holding chain of swing. (Thumb was in closed position and force of chain during momentum of swinging opened it; thumb thereafter would not lock.)	Malfunction, occurring one day after fitting, caused by loose-fitting thumb axis pin working out of position, thus permitting thumb spring to slip off thumb activating arm. (Staking of thumb axis pin was suggested and no thumb malfunctions have subsequently been attributed to this defect.)
			One thumb, probably two, broken when child fell.	Malfunction occurring after 61 days' wear, caused by thumb boss wearing away, either because of excessive load on thumb or notch being too shallow to carry normal loadings.
11	Cable frayed (3), or broken (8) (cable break sometimes preceeded by extremely hard pull)	7, 7, 7, 17, 60, 61, 70, 90, 111, 113, 215	Sharp bend in cable housing (usually caused by use of Hosmer WE-200 or larger wrist unit)	Short-axis diameter of hand too small.
(2-3)			(In addition, 2-3 frayed or broken cables were replaced by local prosthetists.)	
2	Backlash (secondary to other malfunction in all but two hands)	0, 0 (fitting visit)	Prosthetist, in adjusting "Bac-Loc," carelessly forced adjustment screw, twisting it in half and destroying "Bac-Loc" function.	None known.
			Thread of Allen screw, used to adjust "Bac-Loc", stripped (again probably due to carelessness of prosthetist)	

*All hands used in the Left-Hand Study were identical with the "new modified" right hands.

APPENDIX B, PART II (Cont'd)

MALFUNCTIONS OF APRL-SIERRA NO. 1 HAND (LEFT)*

N	Description	Range of Wear (days)	External Cause	Internal Cause
11	Finger mechanism jammed, or rough cable action; fingers stuck in open position or did not close completely	0, 0, 0, 21,59,61, 63,69,83, 90,140	Two hands could not close completely, one of these at fitting visit. (Cause unidentified)	
			Nine hands had rough cable action. (in one instance action caused by piece of broken "Bac-Loc" adjustment screw lodging under "Bac-Loc" roller; in other hands, probably caused by water, dirt and other foreign matter entering hand).	Inspection of some hands before fitting indicated rough cable action, attributed to improper centering of operating cam in frame, causing rubbing of cam against sides of hand frame. (This misalignment was possibly aggravated with use.)
			One hand temporarily had fine "jerk or catch". (attributed to foreign matter inside)	
2	Stud broken from base plate	59,83	Probably due to falls	
1	Floating fingers completely detached	139	Not known (However, same child damaged glove by crawling on cement surface.)	
1	Shattered middle finger	63	Fall	
4	Protrusion of pin at base of thumb	1,7,60, 69		Thumb-axis pin loose in hole, not properly "staked". (Manufacturer subsequently "staked" thumb-axis pins.)

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*All hands used in the Left-Hand Study were identical with the "new modified" right hands.

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